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Maritimes Region

Evaluation of Fishery Independent Surveys as Assessment Tools for Lobster Fishing Areas (LFAs) 34-38

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Foreword

This series documents the scientific basis for the evaluation of aquatic resources and ecosystems in Canada. As such, it addresses the issues of the day in the time frames required and the documents it contains are not intended as definitive statements on the subjects addressed but rather as progress reports on ongoing investigations.

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ABSTRACT

Fishery-independent data are needed to fully assess lobster stock status in the Maritimes Region. In the areas covered by Lobster Fishing Areas (LFAs) 34-38, there have been several types of surveys that were designed to target other species. These surveys are the Fisheries and Oceans Canada (DFO) Maritimes Region Summer Research Vessel Survey (RV survey), an industry-sponsored survey for groundfish (Individual Transferrable Quota, or ITQ survey) and several surveys for scallops (Scallop surveys). All three survey types collected data on lobster abundance and demography. Because of differences in gear selectivity and survey timing, the surveys provide a different window on the population than that provided by commercial traps. This document includes survey data up to the end of 2012; in 2013 the ITQ survey began a transition to a more lobster-focussed survey.

The survey types (RV, ITQ and Scallop) show the same broad trend of increased lobster catch rate (number per tow) over the last 10-15 years, similar to trends in landings and commercial catch rate. Each survey has strengths and weaknesses in providing data on lobster. The RV survey catch rate is suggested as an interim primary indicator for lobster abundance of LFAs 35-38. The catch rate in the ITQ survey (and its revamped version) is suggested as a primary indicator for lobster abundance for LFA 34. The ITQ survey covered all of the LFA 34 fishing grounds and catch rates were much higher in the nearshore (mean of over 240 lobsters per tow in recent years), compared to the midshore and offshore (8-15 lobsters per tow in the midshore and less than 5 in the offshore). The scallop surveys have high sampling intensity but more limited geographic coverage and a shorter time series. The scallop gear appears to capture smaller lobsters than the other gear types and these surveys could provide a useful secondary indicator of the abundance of juvenile lobsters on scallop grounds.

Évaluation des relevés indépendants de la pêche comme outils d'évaluation pour les zones de pêche au homard (ZPH) 34 à 38

RÉSUMÉ

Les données indépendantes des pêches sont nécessaires pour évaluer dans son ensemble l'état du stock de homard dans la région des Maritimes. Dans les zones couvertes par les zones de pêche au homard (ZPH) 34 à 38, il y a eu plusieurs types de relevés qui ont été conçus pour cibler d'autres espèces. Il s'agit des relevés suivants de Pêches et Océans Canada (MPO) : le relevé d'été du navire de recherche du MPO dans la Région des Maritimes (relevé du NR), un relevé parrainé par l'industrie relatif aux poissons de fond (quotas individuels transférables ou relevé de QIT) et plusieurs relevés relatifs au pétoncle (relevés de pétoncles). Les trois types de relevés permettent de recueillir des données sur l'abondance et la démographie des homards. En raison des différences de choix des engins de pêche et de période pour chaque relevé, les relevés fournissent un aperçu des populations différent de celui fourni par les casiers commerciaux. Le présent document comprend des données provenant de relevés effectués jusqu'à la fin de l'année 2012. En 2013, le relevé de QIT a commencé sa transformation vers un relevé axé surtout sur le homard.

Les relevés du NR, de QIT et de pétoncles indiquent tous la même tendance générale d'augmentation du taux de capture du homard (nombre de homards par coup de filet) au cours des 10 à 15 dernières années, semblables aux tendances de débarquements et de taux de capture commerciale. Chaque relevé a ses forces et ses faiblesses concernant la collecte de données sur le homard. Le taux de capture du relevé du NR est proposé comme principal indicateur provisoire de l'abondance du homard dans les ZPH 35 à 38. Celui du relevé de QIT (et sa version remaniée) est proposé comme principal indicateur de l'abondance du homard dans la ZPH 34. Le relevé de QIT couvrait tous les lieux de pêche de la ZPH 34 et les taux de capture étaient beaucoup plus élevés dans le secteur côtier (en moyenne, plus de 240 homards par coup de filet au cours des dernières années) que dans les secteurs semi-hauturier et hauturier (entre 8 et 15 homards par coup de filet dans le secteur semi-hauturier, et moins de 5 dans le secteur hauturier). Les relevés de pétoncles comportent un échantillonnage à intensité élevée, mais la couverture géographique est plus limitée et la série chronologique est plus courte. Les engins de pêche au pétoncle semblent capturer des homards de plus petite taille que les autres types d'engins et ces relevés pourraient servir d'indicateur secondaire de l'abondance des homards juvéniles sur les lieux de pêche au pétoncle.

INTRODUCTION

The lobster fishery in Lobster Fishing Areas (LFAs) 34-38 has traditionally been monitored and assessed using only fishery dependent data such as commercial landings and catch rate. Standard lobster traps such as Fishermen and Scientists Research Society (FSRS) recruitment traps (Tremblay et al. 2009a) are better for long-term abundance indicators than commercial traps because their design is fixed. However, they are still fishery dependent since they are fished alongside commercial gear during the regular fishing season. While fishery dependent data can provide useful indicators of trends in lobster abundance, indicators based on these data have caveats that include:

1. the influence of lobster behavior on trap catches (catchability),
2. the highly selective nature of traps,
3. restriction to the commercial fishing season,
4. potential changes in fishing strategy and efficiency over time, and
5. potential changes in fishing regulations that affect landings and catch rate.

For all of these reasons, the development of fishery independent indicators has been recommended for lobster assessment in the Gulf of Maine (DFO 2006, Pezzack et al. 2006, DFO 2007). Fishery independent data would allow a more comprehensive analysis of the state of lobster populations. The current research document was tabled as a working paper at a framework meeting in February 2013 (DFO 2013). The fishery independent data available at the end of 2012 were surveys designed for other species, and include two trawl surveys and several scallop surveys. The trawl surveys are the Fisheries and Oceans Canada (DFO) Maritimes Region Summer Research Vessel Survey (RV survey) and an industry-sponsored survey for groundfish (Individual Transferrable Quota, or ITQ survey). The surveys differ with regard to gear type and areal coverage, but there are areas of overlap for comparison. The scallop survey data is examined for several areas in LFA 34 and the Bay of Fundy.

As of 2013, the ITQ survey was discontinued in its existing form and is in the process of being transformed into a lobster-focussed survey.

METHODS

MARITIMES SUMMER RESEARCH VESSEL (RV) SURVEY

The methods and design of the DFO Maritimes Region RV Surveys are described in greater detail in several publications: Clark et al. (2010), DFO (2011), and Stone and Gross (2012).

The RV survey has been conducted annually since 1970 and was designed to provide abundance trends for groundfish residing at depths from about 50 m to 400 m (Clark et al. 2010). Lesser depths are sampled in the Bay of Fundy strata (as shallow as 27 m or 15 fathoms), but sets less than 50 m represent a small portion of the total (5.5% of sets between 2005 and 2012, most 40-50 m). There are 2-10 tows per stratum depending upon stratum size and variability in cod and haddock abundance within the stratum. The survey follows a stratified random sampling design (Figure 1), and includes both hydrographic sampling and sampling of fish and invertebrates using a bottom otter trawl. The target duration and speed for each trawl is 30 minutes at 3.5 knots, for a tow distance of 1.75 nautical miles or 3.2 km. For estimates of swept area, a standard wing spread of 12.5 m (41 ft) is used, resulting in a standard area swept (“trawlable unit”) of 40,000 m^2. For some fish species that can be “herded”, the door spread may be a better indicator of swept area (Clark 1993), but for lobsters wing spread is likely best (Don Clark, pers. comm).

The calculated number per tow and kilogram (kg) per tow are adjusted to correct for variations in tow length. All numbers per tow presented in the current document are arithmetic means weighted by stratum areas obtained from the DFO Maritimes Region Population Ecology Division Virtual Data Centre (VDC). The VDC process involves estimating the total number of lobsters for each stratum (based on the mean number per tow and the stratum size) and then summing the stratum totals to get the estimated total number of lobsters for all selected strata. The VDC calculates the stratified mean number per tow by dividing the estimate for total number across strata by the number of trawlable units in the strata.

There were changes to the net used and in the vessel conducting the survey in 1982 and 1983, along with some changes in data collection protocols. These are described in the text-table below. These changes may affect the biomass trends for some species and, while the early data are presented, all indicators are based on the data from 1983 to present.

Years	**Vessel**	**Design**	**Trawl**
1970-81	RV *AT Cameron*	side-trawler	Yankee 36 trawl.
1982	RV *Lady Hammond*	stern-trawler	Western IIA trawl.
1983- present	CCGS *Alfred Needler*	stern-trawler	Western IIA trawl

When the *Alfred Needler* was unavailable in 2008, the sister ship, CCGS *Wilfred Templeman*, was used as a replacement. In 2004 and 2007, sampling was conducted using the CCGS *Teleost*. No conversion factors were developed to adjust species-specific catches in 2004, 2007 or 2008.

The stratified random sampling design allows the station locations to be spread over the entire area, provides differential sampling intensity among strata, and facilitates analyses over various geographic regions corresponding to different stock or management definitions. However as the surveys were designed for groundfish the survey timing and strata may not be optimal for lobsters. The gear used is also not optimal for catching lobsters, but it is believed that the survey catch rates are proportional to abundance in the areas surveyed, although it is expected that this holds only when lobster abundance is above a certain threshold. At low abundance, lobsters may retreat to more structured habitat that is inaccessible to trawls.

Shallower areas (less than 50 m depth) which tend to be nearer shore in LFA 34, and where lobsters are often most abundant, are not sampled by the RV survey. In addition, large areas of LFA 34 are not sampled due to untrawlable bottom. The result is that data are only available for the Bay of Fundy primarily at depths greater than 50 m, the deeper water of the Gulf of Maine, the offshore banks (Browns, Georges, Sable, etc.), and upper slope region. Data are not available for German Bank and the nearshore areas of LFA 34 or any of the other lobster grounds along the Atlantic coast of Nova Scotia (LFA 27-33).

Survey strata (Figure 1) were defined by depth (Figure 2) and do not correspond to LFA lines. For this reason, the data in this report are examined using the following strata groupings:

1. Bay of Fundy and approaches: strata 490-495 (LFA 35-38 plus Bay of Fundy portion of LFA 34).
2. Eastern Gulf of Maine (Bay of Fundy/Gulf of Maine/Browns Bank): strata 480-495.

Beginning in 1999, the RV survey protocol was modified to collect more data on selected invertebrates, including lobsters (Tremblay et al. 2007). All lobsters were measured to the nearest millimetre (carapace length; CL) and sexed. As well, a total catch weight was recorded. From 1999-2012, the number of sets per year in strata 490-495 averaged 20.6 (range of 15-29); for strata 480-495, the number of sets per year averaged 49.7 (range of 38-59).

During the 1983-1998 period, lobster numbers and total weight of the catch were recorded but no detailed measurements were taken. Concern has been raised as to the completeness of the data in some of these years but DFO personnel who participated in the surveys indicate that to their knowledge all lobsters were weighed and counted. During this period, there is a great deal of year-to-year consistency in the levels of the catch (see Results) suggesting that any deviation from the protocol was likely small. During 1995-1998, the protocol was modified and only lobster weight was recorded. To estimate number per tow for this period, the mean number and weight of lobster was calculated for the six years before and after 1995-1998. The estimated mean lobster weight was then used to estimate number per tow for the 1995-1998 period.

Prior to 1983, samples were sorted on deck, and it has been suggested that counts and weights before this period may be less reliable as lobsters were not a priority species to be measured. In addition, there was a different vessel prior to 1983, which may have affected the trawl catch.

The availability of data from the longer running USA surveys provides a check on the quality and consistency of the Canadian data. Where they overlapped in the Gulf of Maine and Browns Bank areas, the two surveys show similar trends in lobster catch rates, indicating that, if the recording of lobsters was inconsistent on DFO surveys, it did not result in a bias.

To evaluate the indicators developed from the trawl surveys, their trends were compared with the existing fisheries indicators: landings and commercial CPUE. Data from the fishing season following the survey was compared with the RV survey catch rate using the following rationale. The RV survey occurs in July, after the lobster fishery is closed (LFA 34, May 31; LFAs 36 and 38, June 29), or near the end of the fishing season (LFA 35, July 31). The legal-sized lobsters caught in the July survey represent what was left over from the fishery. Few lobsters have molted by the time of the survey. Lobsters below the legal size, not removed by the fishery, will moult and most of those greater than 70 mm CL will enter the legal size range and be available in the next fishing season. Thus a substantial portion of the lobsters caught in the RV surveys (those below the legal size) reflects what will be available as legal sizes in the following fishing season. For this reason, the survey catch rates in year t are compared with the landings in the fishing season in year t to year t+1. For example, the 2011 RV survey catch rate is compared to lobster landings in the fishing season beginning in fall 2011 and ending May 31 2012.

INDIVIDUAL TRANSFERABLE QUOTA (ITQ) SURVEY

The ITQ survey began in 1995 to obtain information on the abundance of cod, haddock and winter flounder in inshore areas not sampled by the annual RV trawl survey. Since its beginning, the ITQ survey has consistently captured lobsters, particularly in LFA 34. The ITQ survey has recorded lobster numbers since 1996 and, beginning in 2005, more detailed data on lobster (size, sex) were collected as part of the sampling protocol.

Of the three surveys considered here, the ITQ survey captures the most lobsters. Between 2010 and 2012, 4173-4976 lobsters were measured annually during the survey. Of these, approximately 3836-4495 were from LFA 34, 114-285 from LFAs 35-38 and 132-195 from LFAs 40 and 41. By comparison, during the same period the RV survey measured 490-1486 lobsters per year. Of these, 320-831 were in strata 480-495 and 157-627 were in strata 490-495. The scallop survey measured 1033-1789 lobsters per year (LFAs 34 and 35-38) of which 381-712 lobsters were from the Bay of Fundy.

The ITQ survey was a fixed station survey that occurred in July of each year. In 1995, polygons were set up and industry participants selected a station location in each of the polygons (Figure 3). These stations were then meant to be trawled in future surveys. There were 180 stations in Northwest Atlantic Fisheries Organization (NAFO) Division 4X (Figure 4); 50-60 of these were sampled in LFA 34 in each year from 1995-2012. The gear was a 280-balloon trawl (14-inch cookie rock hopper footgear, 1 ¼-inch cod end liner) with a wingspread of approximately 17 m (55'). Tows were one nautical mile (1.85 km) in length and generally 20 minutes in duration. As such, the approximate area swept per tow was 31,450 m^2.

The ITQ fixed stations remained relatively consistent over the survey period; however, over time, some stations were dropped and others added. To avoid potential biases introduced by stations not represented over the entire survey, only stations sampled in the last 10 years and in greater than 15 of the years were used.

To allow for comparison with the LFA 34 lobster fishery data, the stations were assigned to the lobster reporting grids and the nine LFA 34 Grid Groups (GG) used in the LFA 34 assessments (Figure 5). The LFA 34 Grid Groups have been further combined into Nearshore (GG 1, 2a, 2b), Midshore (GG 3, 4a, 4b), Offshore (GG 5, 6) and Bay of Fundy (GG 7) (Figure 6). The Grid Groups are based on depth, and the Midshore, Offshore and Bay of Fundy (GG 7) correspond closely to the Maritimes Region Summer RV Survey strata.

Following the same rationale for comparing RV trawl catch rates with landings, the ITQ survey catch rates in year t are compared with the landings in the fishing season in year t to year t+1.

SCALLOP SURVEYS

Surveys for sea scallops were conducted annually from the early 1980s to the present to assess abundance (Sameoto et al. 2012, Smith et al. 2012; Figure 7). These surveys started in the Bay of Fundy in 1981 and were extended into the area off southwest Nova Scotia in 1991 (Table 1). Surveys in Scallop Fishing Area 29 (portions of GG 2a, 2b and 4a) began in 2001.

The survey gear is multiple dredges or drags ("Digby drags"); a comparison of two types of scallop drags found no difference in catch rate standardized by area swept (Smith et al. 2013). Tows are 8 minutes in duration at 2.5-3.5 knots. Catches of scallops and other species are standardized to an 800 m tow length and a tow width of 17.5 feet (5.334 m) for an area swept of 4267 m^2. Although the scallop tows have a much smaller swept area than the RV and ITQ tows, they are much more numerous. For example from 2006-2010 there were 1676 scallop tows in LFA 34 (Table 1). During the same time period the ITQ survey conducted less than 300 tows in LFA 34.

Lobsters are caught as a bycatch at a subset of the stations (Figure 7) and are measured prior to being returned to the ocean. Scallops are typically found on gravel sea bottoms, a habitat not favored by lobsters (Tremblay et al. 2009b), but the two species do overlap in some areas.

The timing of scallop surveys has changed over time (Table 1). They were conducted primarily in June for the first 10 years but have occurred over a wider range of months since the 1990s (Table 1). Scallop surveys that occurred prior to July can be considered pre-molt; those in July and August overlapped the lobster moulting period. To reduce the problem of combining or comparing pre- and post-moult size frequencies or catch rates, only surveys conducted from May to June and from September to November are considered here.

To allow for comparisons with the LFA 34 lobster fishery data the stations were assigned to the lobster reporting grids and the nine LFA 34 Grid Groups (Figure 5) as described for the ITQ survey.

RESULTS AND DISCUSSION

MARITIMES SUMMER RV SURVEY 1970-2012

Application to Bay of Fundy (Strata 490-495)

Spatial trends

Changes in geographic range or depth range can be an indicator of changes in population size or shifts in distribution due to environmental changes. Two indicators are used, one qualitative and the other quantitative. The qualitative approach is a simple examination of the distribution of catch by set as illustrated in the maps. The maps (Figure 8) clearly show that over the years there has been an increase in the number of sets with lobsters.

Spatial changes can be examined quantitatively by determining the number of sets with lobsters (non-null sets). At low abundance, fewer sets will contain lobsters. If abundance is increasing in a few areas, we would expect increased catch rates in a few sets or areas, without an increase in the proportion of sets with lobster. However if an abundance increase is widespread, then a greater portion of sets will contain lobsters.

The proportion of sets with lobsters increased from less than 20% in the mid-1990s to over 70% since 2002 in the Bay of Fundy (Figure 9). The proportion of sets with lobsters in 2007 was low compared to adjacent years, but given the relatively low sampling intensity (approximately 20 sets per year), variability in survey-based indices is to be expected with a random design. The increased percentage of sets since 2002 indicates a wider distribution of lobsters at sufficient density to be caught routinely in the trawl survey. The increase in non-null sets is correlated with the observed increases in landings (Figure 9 and Figure 10).

Stratified mean catch rate in RV Trawl surveys (1970-2012)

Mean catch per tow is widely used as a proxy for abundance for different species. It has been used in the USA lobster assessments and is an input to models such as the University of Maine lobster model (Chen et al. 2005). In a long-lived species like lobsters with consistent fishing pressure, large year to year variations in abundance would not be expected. Annual changes in the mean per tow could be the result not only of changes in abundance but to changes in (i) lobster distribution and (ii) availability to the trawl. In addition, there will be sampling variability associated with low sampling intensity and a stratified random design. As such, a three year moving average is used to smooth year to year variations in number per tow that are most likely not related to abundance.

The stratified mean number per tow in the Bay of Fundy strata (490-495) was consistently low from 1970 to the late 1990s and then increased with two high years in 2003 and 2004 (Figure 11). Numbers increased dramatically in 2011 and 2012. Although not a steady annual increase, the increasing trend in the RV Survey for these strata reflects the increasing trend in the landings for the Bay of Fundy (Figure 12).

Application to wider area and LFA 34 (Strata 480-495)

The Maritimes Region Summer RV Survey does not cover the shallower portion of LFA 34 (less than 100 m, Figure 1) and thus cannot be used as the only abundance indicator for LFA 34. However, the trends observed in the RV survey in the Bay of Fundy are also present in survey results in the Gulf of Maine, Browns Bank and Georges Bank suggesting a common underlying cause of the recent increases in abundance for this large area. For this reason, RV survey data from Browns Bank, Gulf of Maine and Bay of Fundy (Strata 480-495) are used to assess the overall trends for the Eastern Gulf of Maine area, which may serve as a proxy for LFA 34 (Figure 13).

The mean number per tow for the Eastern Gulf of Maine shows a pattern similar to the LFA 34 landing patterns in the last 20 years (Figure 14). However, there is a difference in the mean number per tow and LFA 34 landings trends during the 1980s. During this period lobster landings increased but the Maritimes Region Summer RV Survey number per tow did not.

Potential explanations for the observed difference in the mid-1980s are provided below.

1. High landings in LFA 34 were due to increased abundance in the shallower nearshore and midshore areas not sampled in the RV survey

During the 1980s, lobster landings increased over much of the range of lobsters, particularly in nearshore and warm water areas (Rhode Island, Massachusetts, LFA 27-33, Southern Gulf etc.). One of the few regions where this did not occur was in Maine or the Bay of Fundy. If the observed increase in LFA 34 landings in the 1980s was due to an increase in abundance in the shallower nearshore portions of the fishery, but not in the deeper waters, it would not have been reflected in the RV survey, which does not sample the nearshore areas.

2. The increase in abundance in the 1980s occurred in more structured habitat not accessible to the trawl survey.

It might be expected that abundance would increase first in prime habitat, which for lobsters is rocks and boulders on sand. Trawls in this habitat can get damaged and hooked on the bottom.

3. High landings in LFA 34 were due to the shift in effort from nearshore to more offshore areas during the 1980s and this was responsible for more of the landings increase than previously thought.

The shift in fishing effort from the traditional nearshore during this period was observed but the lack of logbooks at the time made it impossible to quantify it directly. Based on interview studies it was estimated that the deeper water mid and offshore portions of LFA 34 accounted for 10% of the landings by 1994 (DFO 2001). If these estimates are correct, the shift in effort would not account for the observed increase in landings.

4. Lobsters were not completely recorded in the survey in the earlier years of the survey.

This possibility has been raised in the past but information available indicates this was not a serious problem and would not explain the discrepancy between the surveys and landings.

Lobster size frequencies

In addition to data on lobster abundance, the trawl survey provides data on lobster size and sex. This can be monitored and in the future abundance at size indictors could be developed to track sex ratios, recruitment and abundance of mature sizes (Figure 15). The increasing numbers of lobsters caught in later years is reflected in the higher samples sizes from 2008-2012. The RV survey occurs mainly in July, before the peak in annual lobster molting, and in most size frequency plots there is a drop-off at sizes above the minimum legal size. Because the RV survey does not sample the shallower nearshore areas, the drop-off is not as great as is apparent in the nearshore samples from the ITQ and scallop surveys (discussed below). Females with eggs are apparent in the RV survey size frequencies, with observations beginning at sizes just above the minimum legal size.

Summary: Maritimes Region Summer RV Survey

LFA 34

- The Maritimes Region Summer RV Survey has reduced value for LFA 34 because it is restricted to the deeper water portions of LFA 34 and as such does not cover the areas of greatest lobster abundance which have represented the bulk of lobster landings.
- It may be possible to use the RV survey results for strata 480-495 as a secondary indicator of trends in LFA 34 abundance, but there are important caveats: if lobster abundance declines and lobsters retract to shallower or more complex habitats not sampled by the RV survey the index will not be useful.

LFA 35-38

- RV Survey strata 490-495 corresponds closely to the area of LFAs 35-38 and the Bay of Fundy portion of LFA 34.
- The RV Survey is restricted mainly to depths greater than 50 m and therefore does not cover the shallower grounds where much of the lobster fishery occurs.
- Survey trends in both mean number per tow and proportion of sets with lobsters have increased in recent years and the increases correspond with increased lobster landings.
- The increase in proportion of sets with lobsters suggests that lobsters increased in abundance over much of the survey area.
- Mean number per tow in the Summer RV survey in strata 490-495 is proposed as an interim primary indicator for tracking changes in lobster abundance in the Bay of Fundy, and proportion of sets with lobsters is proposed as a secondary indicator useful in understanding the observed abundance trends and potential changes in distribution.
- Due to the relatively small number of lobsters measured (157-627 in years of highest catch rates), the RV survey is of marginal value in tracking changes in size structure in the Bay of Fundy.

ITQ SURVEY 1995-2012

Spatial trends and mean number per tow

Since 1995 there has been an increase in the number of lobsters per trawl and in the number of sets with lobsters (Figure 16). The mean number per tow in LFA 34 has increased since the survey began in 1995 with the largest increase in 2010 (Figure 17). Catch rates by subareas (nearshore, midshore and offshore) illustrate the much higher catch rates in the nearshore portion of the LFA (Figure 18). In the nearshore, catch rate averaged over 240 lobsters per tow in each of the last 3 years, compared to 8-15 lobsters per tow in the midshore and less than 5 in the offshore. Plotting the midshore and offshore data on different scales shows similar trends of increased abundance throughout LFA 34 (Figure 19). The trends and levels of the ITQ catch rate in the offshore portion of LFA 34 compare well with the catch rate from the RV survey in the one fully offshore stratum within LFA 34 (stratum 484) (Figure 20) and the catch rates are well correlated ($r^2 = 0.59$). With regard to the portion of the ITQ survey in the Bay of Fundy (corresponding to LFAs 35-38), an increase in survey catch rate is apparent that compares well with the RV survey results for this area (Figure 21). Using data from overlapping areas in the Bay of Fundy, the two surveys are moderately well correlated ($r^2 = 0.37$) over the period 1995-2012.

Survey catch rate versus fishery landings and CPUE

There is a positive relationship between ITQ survey number per tow and (i) landings and (ii) commercial CPUE. The ITQ survey trends reflect the overall increasing trend in the total landings for LFA 34 (Figure 22 and Figure 23) and in the Midshore, Offshore and Bay of Fundy (GG 7) subareas (Figure 24 and Figure 25). There is no apparent relationship between nearshore landings and the ITQ catch rate (Figure 24 and Figure 25). Similar trends are observed in the relationship between the commercial CPUE reported in fishermen's logs and the number per tow in the ITQ survey (Figure 26).

In some cases it appears that commercial CPUE levels off at higher abundance or that the commercial CPUE rate of increase slows as abundance increases (at least as indicated by ITQ catch rate increases – Figure 26). This may indicate that commercial traps are becoming saturated, although further work would be needed to confirm this as the commercial CPUE plateaued at different levels depending on area. In the Bay of Fundy portion commercial CPUE appears to level off at less than 1.2 kg per trap haul, but in the midshore and offshore portions of LFA 34, commercial CPUEs of 1.4-1.7 kg trap haul have been measured from 2009-10 to 2011-12 (Figure 26).

In the Nearshore subarea, commercial landings and CPUE have not trended in the same manner at the ITQ number per tow (Figure 26). The largest discrepancy between landing trends and the ITQ survey number per tow is observed in the nearshore GG 2a (Lobster Bay) (Figure 27) where overall landings have declined and commercial CPUE has stayed flat, while the number per tow in the ITQ survey has increased. This discrepancy between fishery production and abundance based on the survey is likely related to a decline in effort documented for some nearshore areas (Tremblay et al. 2013). However this cannot be the only explanation as commercial CPUE remained flat as well. The lack of an increase in commercial CPUE may reflect that the lobsters that are surveyed in July are not all available to the fishery in the following Dec-May, perhaps because of movement to deeper waters or because a substantial proportion of lobsters sampled in the survey are below the minimum legal size.

Lobster size frequencies

Data on lobster sizes in the ITQ survey (Figure 28) illustrates the high removal rate and knife-edge size selection of the commercial lobster fishery, particularly in the nearshore portion of LFA 34. The ITQ survey occurs just after the fishery closes and typically before the molt. In the nearshore areas surveyed, there is a large drop in numbers of animals just above the minimum legal size of 82.5 mm CL. When compared to the sizes from at-sea samples of the commercial fishery (Figure 29, taken between late November and May), it is clear the survey catches a wider size range of lobsters including sizes between 40 and 60 mm CL. This is also the case for the RV survey in the Bay of Fundy (Figure 15). The 40-60 mm CL size range is much less common in commercial traps because they are designed to catch fewer sublegal lobsters (primary trap design feature is escape vents). The ITQ survey also captures the shift to larger sizes in the offshore of LFA 34 (Figure 28), although the number of lobsters measured during the survey in the offshore is much lower than that possible from sampling the commercial fishery (Figure 29).

Summary: ITQ Survey

LFA 34

- The ITQ survey provides wide coverage to all areas of LFA 34 including the nearshore area.
- The mean number of lobster per tow in the ITQ survey in LFA 34 has increased since 2000, with the highest values in the past 3 years (2010-12).
- Catch rates are much higher in the nearshore, as compared to the midshore and offshore with a mean of over 240 lobsters per tow in each of the last 3 years, compared to 8-15 lobsters per tow in the midshore and less than 5 in the offshore.

- There is good correspondence between the trends in the ITQ mean number of lobster per tow, fishery landings and commercial CPUE in LFA 34, with the exception of the nearshore where landings are decoupled from the ITQ index. This is likely due to the shift in the fishing effort from nearshore to midshore.
- The mean number per tow in the offshore portions of LFA 34 is of the same magnitude as the RV survey for the same area (1-6 lobster per tow 2009-2012).
- Compared to lobster sizes measured in commercial traps, the ITQ survey samples a wider size range of lobsters including much smaller lobsters than are typically seen in traps but size structure information may be poor and insufficient when catch rates in the trawl survey are low
- The mean number per tow is proposed as a primary indicator for tracking changes in lobster abundance in LFA 34.

LFA 35-38

- The catch rate in the ITQ survey in LFAs 35-38 has increased in the last 10 years, corresponding to an increase in landings in these LFAs.
- The trends and levels correspond between the ITQ and RV survey in areas of the Bay of Fundy where the surveys overlap.
- The ITQ survey, like the RV survey had limited sampling of shallower areas of the Bay of Fundy and because of its shorter time-series and fixed design, has limited value as an abundance indicator.

SCALLOP SURVEYS

Mean number per tow

In the scallop surveys lobsters were caught primarily off southwest Nova Scotia, off Grand Manan, and in the upper Bay of Fundy in the Chignecto Bay area (Figure 30). Due to the more limited geographic coverage of the surveys, and the changes in survey design, the number per tow is depicted only for selected Grid Groups: those that were regularly sampled from 2004-2012, and those with a mean number of lobsters greater than or equal to 1 during that period. These were LFA 34 GG 1, GG 2a, 2b and 4a, and Bay of Fundy GG 4 and 6. Grid Group 2a was the only one sampled in both the May-June and September-November periods. Note that different portions of GG 2a were sampled during the two periods. In May-June it was the northern portion of GG 2a which corresponds to the southern part of Scallop Production Area 3 (Saint Mary’s Bay to Lurcher Shoals area; Smith et al. 2012) whereas in September to November if was the southern portion of GG 2a corresponding to Scallop Fishing Area 29.

In 6 of 7 of the Grid Group/month combinations the number of lobsters per tow increased over the last 10 years, and the 2012 catch rate was the highest (Figure 31). The exception was GG 2a in May-June.

The numbers of lobsters per tow ranged from 0 to 12 in GG 2a and 0 to 8 or lower in the other Grid Groups. This is substantially lower than the numbers per tow in the ITQ survey in inshore Grid Groups, and this is discussed further below.

While the scallop surveys were not designed to assess lobster abundance on a large scale, they could provide a fishery-independent index of abundance for lobsters on scallops grounds.

Lobster size frequencies

The size frequencies of lobsters measured in scallop surveys in the above Grid Groups are shown in Figure 32 (surveys in May-June) and Figure 33 (surveys from September to

November). They clearly show pre-molt (Figure 32) and post-molt (Figure 33) size frequencies. In May-June a large portion of the legal size lobsters has been cropped by the fishery and there is sharp drop off in frequency at the minimum legal size. By the September-November period, a portion of sublegal lobsters has molted into the legal sizes (Figure 33) and the drop off in frequency now occurs after the 90-95 size class. Although the lobsters in GG 2a in Figure 32 are not from exactly the same location as in Figure 33, it is expected that the size frequencies would apply to all of GG 2a within the respective periods.

Comparison of the lobster size frequencies in the scallop survey with those from the other two surveys (Figure 15 and Figure 28) and with the size frequencies from traps (Figure 29) illustrates how each method of sampling has different size selectivity. The scallop survey appears to be better at catching juvenile lobsters less than 30-35 mm CL (Figure 32 and Figure 33), which were not present or rare in the ITQ (Figure 28) and RV survey samples (Figure 15). These gears did not sample the exact same areas, but it is expected that the samples from the nearshore areas represent the size distribution from the nearshore areas as a whole. The scallop gear has the most direct contact with the bottom and may be able to sample smaller sizes than the other gear. Taken together, the data on size frequencies indicates the scallop survey has the potential to be used to develop indicators of juvenile lobster abundance on scallop grounds.

Catch rate in the scallop survey versus the ITQ survey

To evaluate how the size-specific catchability of lobsters in scallop survey gear compares to that of the ITQ trawl gear would require comparisons of the gear in the same time and area using an approach similar to Smith et al. (2013). These data are not available but a coarse comparison of gear efficiency is possible assuming that the samples are representative of the Grid Groups where the tows occurred. In the scallop survey, the mean catch of lobsters from 2009-2012 in May-June in GG 1 and 2a was 3.5-5.1 per tow (GG 1) and 2-5 per tow (GG 2a). Given an area swept of 4267 m^2, the estimate of lobster density from the scallop surveys is 0.0005-0.001 lobsters m^{-2}. The ITQ survey nearshore tows for 2009-2012 had means ranging from 160-275. Given an area swept of 31,450 m^2, the estimate of lobster density from the ITQ survey is 0.005-0.009 lobsters m^{-2}. There are considerable uncertainties in the ITQ estimate because the area swept likely varies with bottom type, but this coarse comparison suggests the ITQ survey is more efficient at capturing lobsters.

The larger area swept of the ITQ survey means that it captures much higher numbers of lobsters per tow than the scallop surveys. On the other hand there are many more scallop tows done per unit area than there are ITQ survey tows. Together these two data sets could be used to evaluate the optimal sample size (tow length and width) for tows directed at lobsters.

Summary: Scallop Surveys

- The catch rate of lobsters in scallop surveys show trends similar to the summer RV and ITQ surveys where comparisons are possible (higher catch rates in the last 10 years)
- Comparison of lobster size frequencies of scallop surveys conducted pre-molt with those conducted post-molt shows a clear shift in size distribution.
- The scallop survey was best at capturing juvenile lobsters (< 30-35 mm CL) which were virtually absent from the other surveys.
- The number of lobsters per tow in the scallop survey could be used to develop abundance indicators for specific grounds, in particular to monitor the abundance on juvenile lobsters.

CONCLUSIONS

The three surveys (RV, ITQ and Scallop) show the same broad trend of increased lobster catch rate (number per tow) over the last 10-15 years. These trends are similar to trends in landings and commercial CPUE. The Maritimes Region Summer RV Survey catch rate has the potential to be a primary indicator for use in establishing a Reference Point for abundance for LFAs 35-38. The main shortcomings of this survey are that it does not cover the shallower portions of the Bay of Fundy and that low sampling intensity results in the capture of relatively low numbers of lobsters. Exclusive use of the RV survey CPUE as an indicator for LFA 34 alone is not recommended since the survey does not cover a larger portion of LFA 34 where much of the fishery occurs. The catch rate in the ITQ survey (or its revamped version, since the survey is changing to a lobster-focussed survey as of 2013) is suggested as a primary indicator for use in establishing a reference point for abundance for LFA 34 and also for LFAs 35-38 in the future. The ITQ survey covered all of the LFA 34 fishing grounds and catch rates were much higher in the nearshore (mean of over 240 lobsters per tow in each of the last 3 years), compared to the midshore and offshore (to 8-15 lobsters per tow in the midshore and less than 5 in the offshore).

The scallop surveys have more limited geographic coverage and because the timing and coverage have changed over time, these surveys represent a shorter time series. The scallop gear does appear to capture smaller lobsters than the other gear types. As such, the data from these surveys could provide a useful secondary indicator of the abundance of juvenile lobsters on scallop grounds. In addition, the data on lobsters from scallop surveys may be very useful in designing a lobster-focussed survey. The surveys are unique in that they provide data before and after the annual lobster molt (usually late July – August), and provide higher spatial resolution (more tows per unit area) than the RV or ITQ surveys.

Spatial trends in the surveys show an expansion of the area with lobster catches, suggesting a widespread increase in abundance and increases in areas that previously supported smaller numbers of lobsters. Contraction in range in the surveys may be an early sign of changes in abundance or recruitment and the proportion of tows with lobsters in the catch may serve as a secondary indicator.

All three surveys collect data on population demography. Because of differences in gear selectivity and survey timing (most surveys outside of the commercial fishing seasons), the surveys provide a different window on the population than that provided by commercial traps. Annual surveys that occur before or after the main lobster moulting period provide a clearer picture of annual differences in size structure. The use of size and sex data from the various surveys offers potential for indicators for recruitment and reproduction. Sampling intensity may need to be increased to develop a more robust broodstock indicator. This may be possible with a revamped version of the ITQ survey.

ACKNOWLEDGEMENTS

Thanks to Julien Gaudette for his careful review and comments on the document, and to Don Clark for comments on the sections describing the Summer RV survey.

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TABLES

Table 1. Number of scallop tows per Grid Group and by month for 5-year periods beginning in 1981. See Figure 5 for a map of Grid Groups. Cells with dashes indicate no data.

		LFA 34 Grid Groups							Bay of Fundy Grid Groups						
Years	**Month**	**1**	**3**	**5**	**7**	**2a**	**2b**	**4a**	**bf1**	**bf2**	**bf3**	**bf4**	**bf5**	**bf6**	**bf7**
1981-1985	All	-	-	-	169	-	-	-	-	1	312	-	9	-	-
	6	-	-	-	169	-	-	-	-	1	312	-	9	-	-
1986-1990	All	-	-	-	104	-	-	-	-	8	465	-	8	-	-
	6	-	-	-	104	-	-	-	-	8	465	-	8	-	-
1991-1995	All	148	225	-	134	14	5	125	-	4	422	-	6	-	-
	6	-	-	-	134		-	-	-	4	422	-	6	-	-
	8	141	189	-	-	14	5	75	-	-	-	-	-	-	-
	9	7	36	-	-	-	-	50	-	-	-	-	-	-	-
1996-2000	All	256	342	10	265	65	3	39	256	237	694	40	88	249	1
	1	-	-	-	-	-	-	-	107						
	2	-	-	-	-	-	-	-	35						
	5	-	-	-	55	-	-	-		80	172		14		
	6	-	-	-	203	-	-	-	6	100	476		31		
	7	-	-	-	7	-	-	-		44	46		5		-
	8	218	342	10	-	65	3	39	29	-	-	17	11	81	1
	9	38	-	-	-	-	-	-	79	13	-	23	27	168	-
2001-2005	All	234	331		259	192	448	205	205	326	932	104	109	176	-
	4	-	-	-	15	-	-	-	-	-	50	-	-	-	-
	5	-	-	-	13	-	-	-	47	19	17	-	7	-	-
	6	108	125	-	97	35	-	2	9	119	446	-	12	-	-
	7	-	-	-	9		-	-	30	23	39	-	1	-	-
	8	126	206		66	50	6	-	93	108	224	7	17	35	-
	9	-	-	-	47	58	244	131	26	41	115	60	40	105	-
	10	-	-	-	12	42	179	43	-	16	41	37	32	36	-
	11	-	-	-	-	7	19	29	-	-	-	-	-	-	-
2006-2010	All	358	286	30	276	152	420	154	447	380	1016	295	136	319	23
	5	51	71	30		10	-	-	-	-	-	-	-	-	21
	6	244	151	-	25	68	-	1		72	140	-	8	-	2
	7	63	64	-	66	24	-	1	12	35	165	203	71	227	-
	8	-	-	-	185	-	-	-	192	139	583	-	17		-
	9	-	-	-	-	8	23	30	201	134	125	92	40	92	-
	10	-	-	-	-	42	397	122	42	-	3	-	-	-	-
2011-2012	All	151	120	-	99	65	154	61	176	141	408	88	58	104	-
	6	151	120	-	23	44	-	-	-	-	36	-	5		-
	7	-	-	-	73	-	-	-	27	71	270	-	4		-
	8	-	-	-	3	-	-	-	149	70	102	88	49	104	-
	9	-	-	-		21	154	61	-	-	-	-	-	-	-

FIGURES

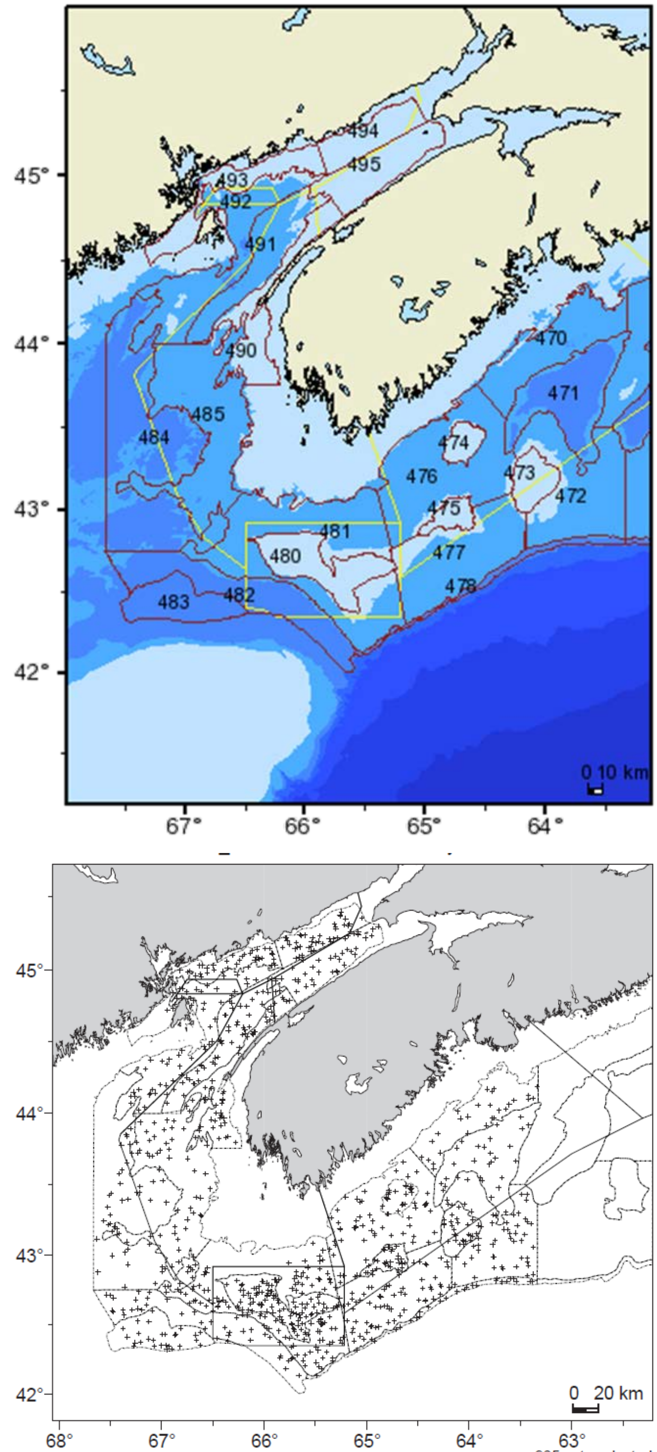

Figure 1. Maritimes Region Summer Research Vessel (RV) Survey locations in NAFO division 4X. Upper panel shows strata in 4X. Lower panel shows station locations sampled 2000-2012. Lobster Fishing Area (LFA) boundaries are indicated by yellow lines in top panel and solid lines on bottom panel.

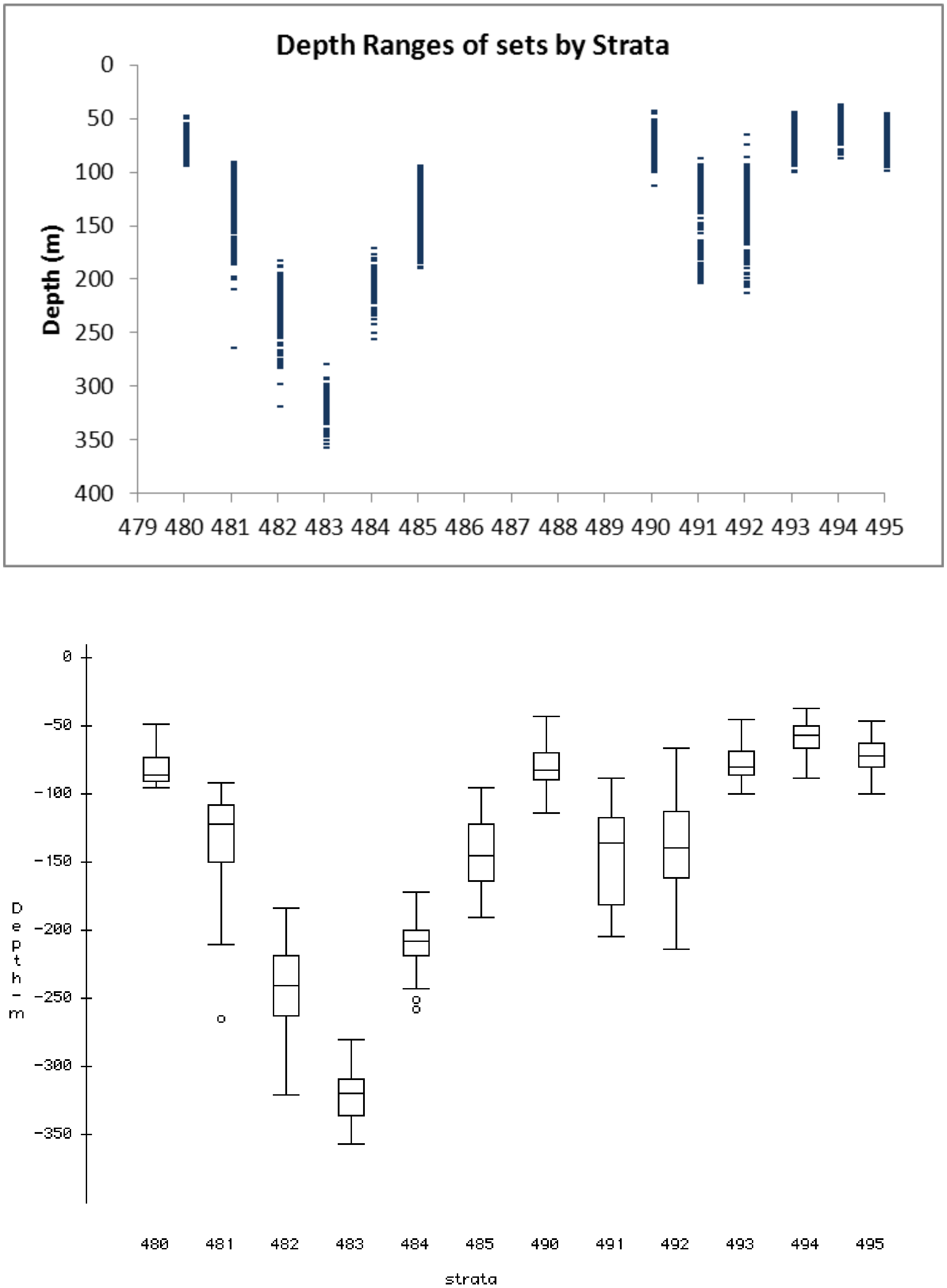

Figure 2. Depth ranges of Summer RV Survey 4X strata 490-495 (1983-2011). Upper panel shows all sets, lower panel shows box plot with median and upper and lower quartiles (box).

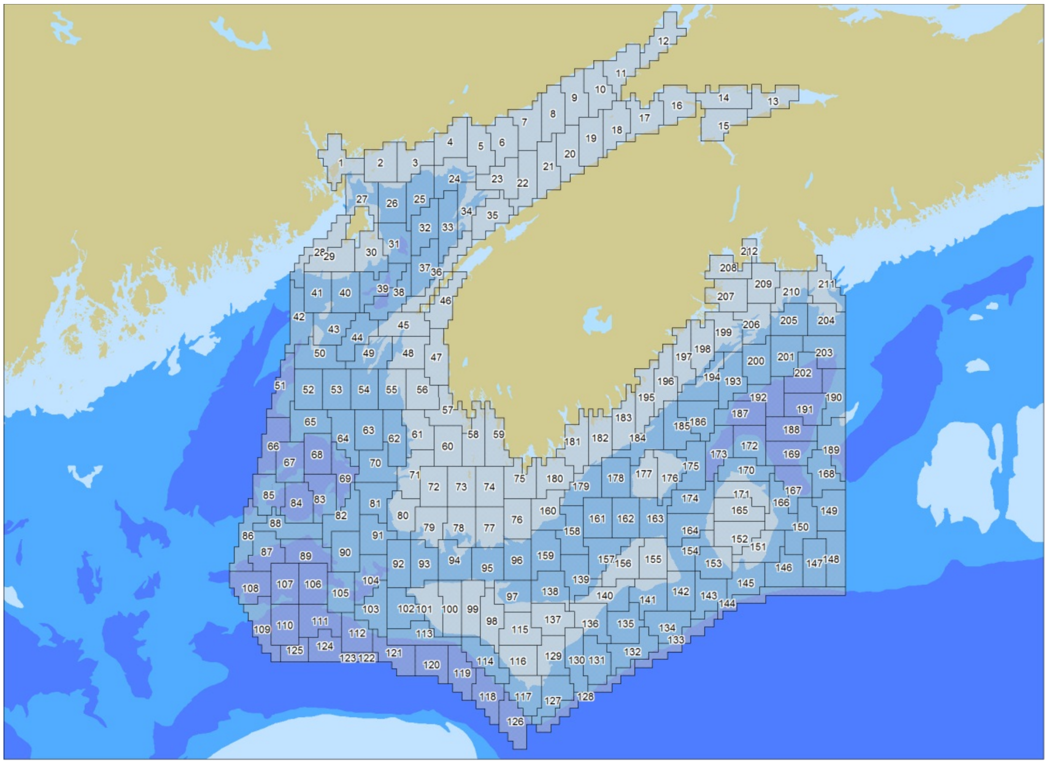

Figure 3. Original polygons for ITQ survey.

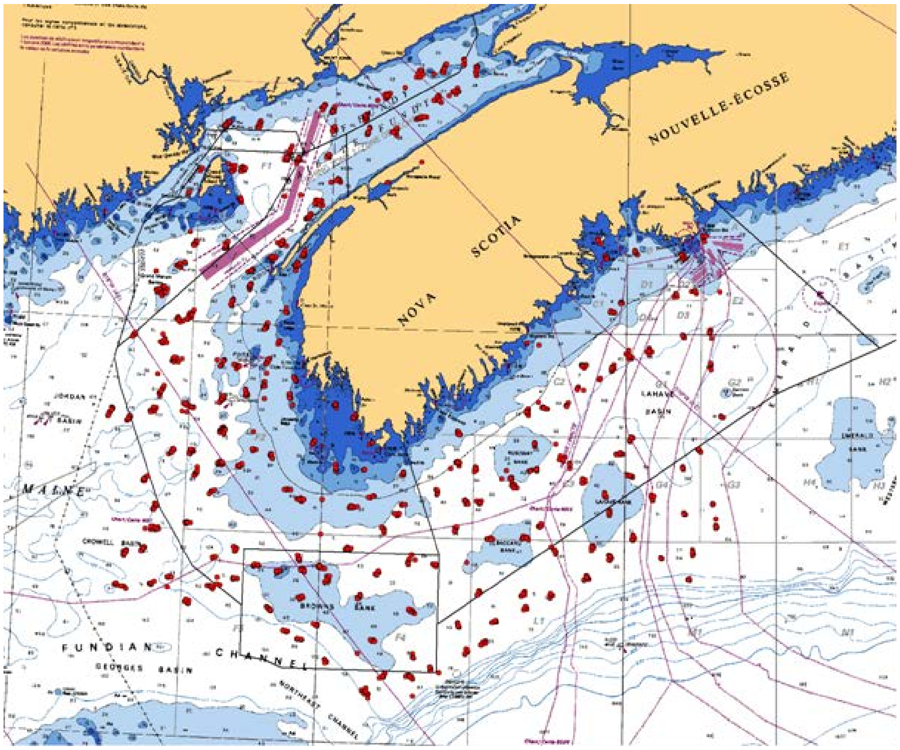

Figure 4. ITQ survey station locations, 1996-2011.

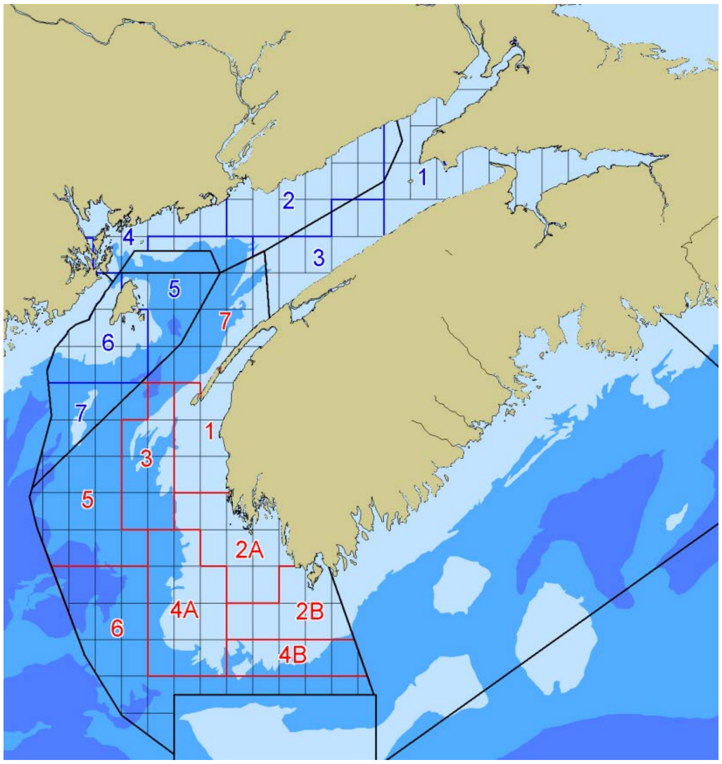

Figure 5. Grid Groups for LFA 34 and Bay of Fundy (based on mandatory logs).

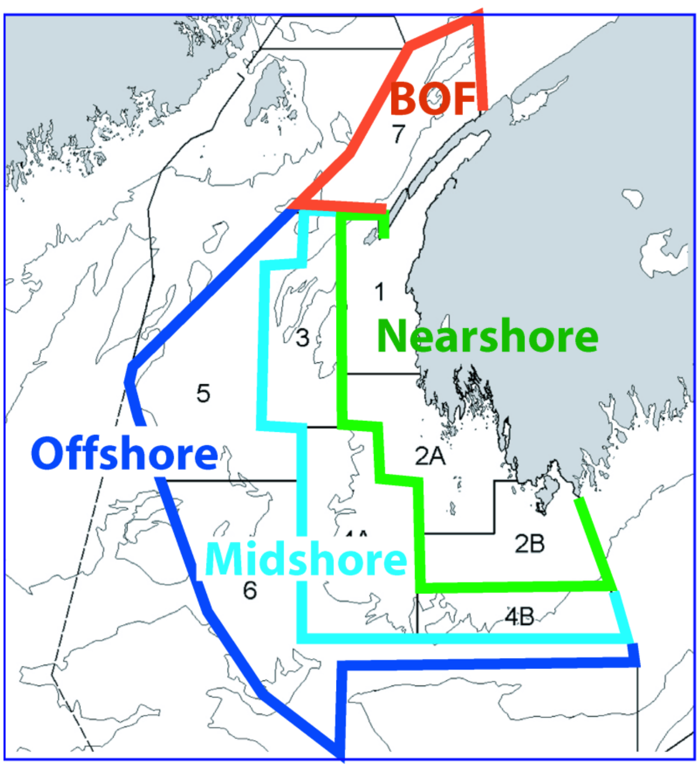

Figure 6. Groupings of LFA 34 grids into Nearshore, Midshore, Offshore, and Bay of Fundy blocks. See Tremblay et al. 2013.

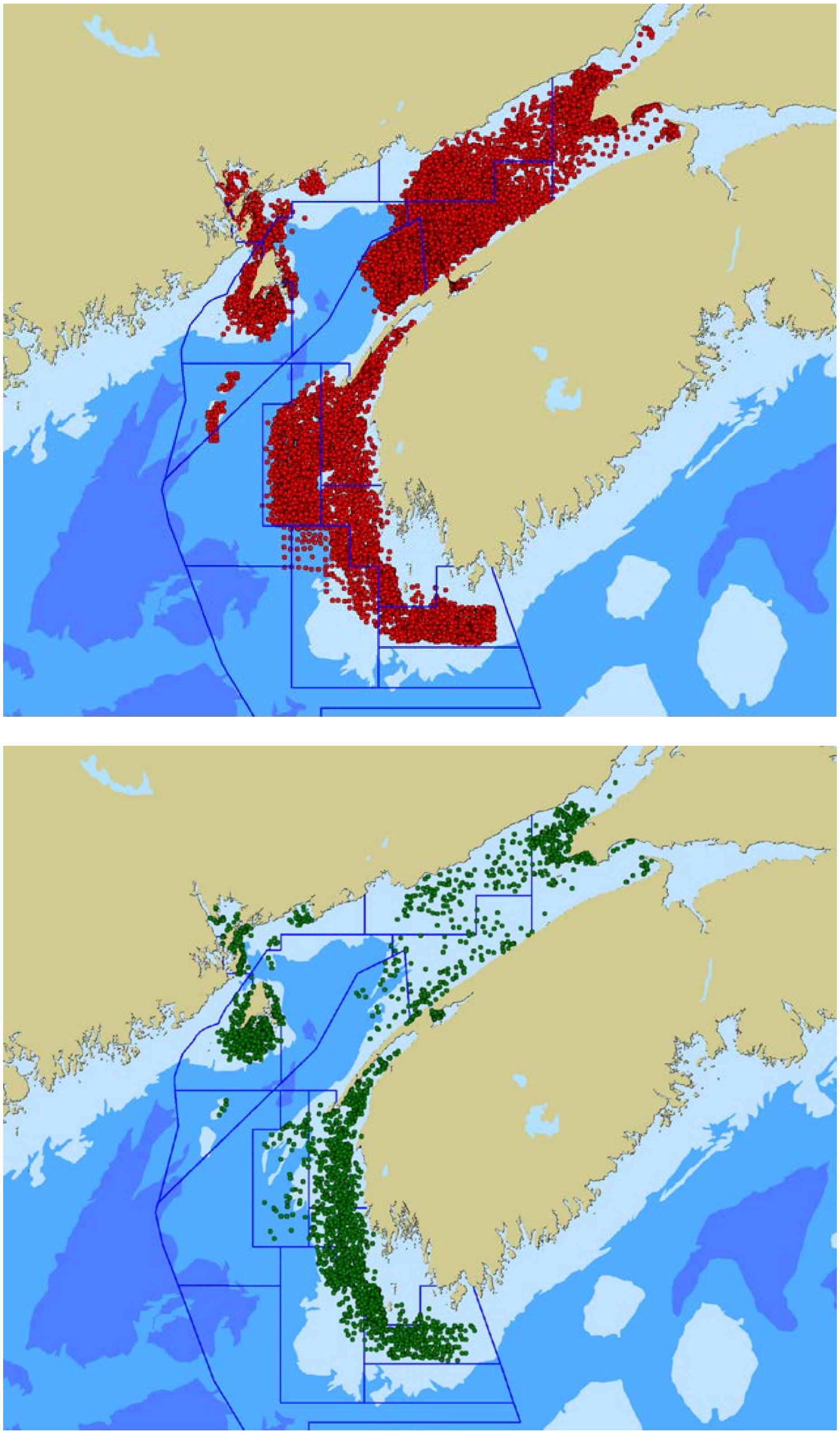

Figure 7. Scallop survey tow locations, 1981-2012. Upper panel shows all stations, lower panel shows locations with lobsters. Lobster Grid Groups superimposed in blue.

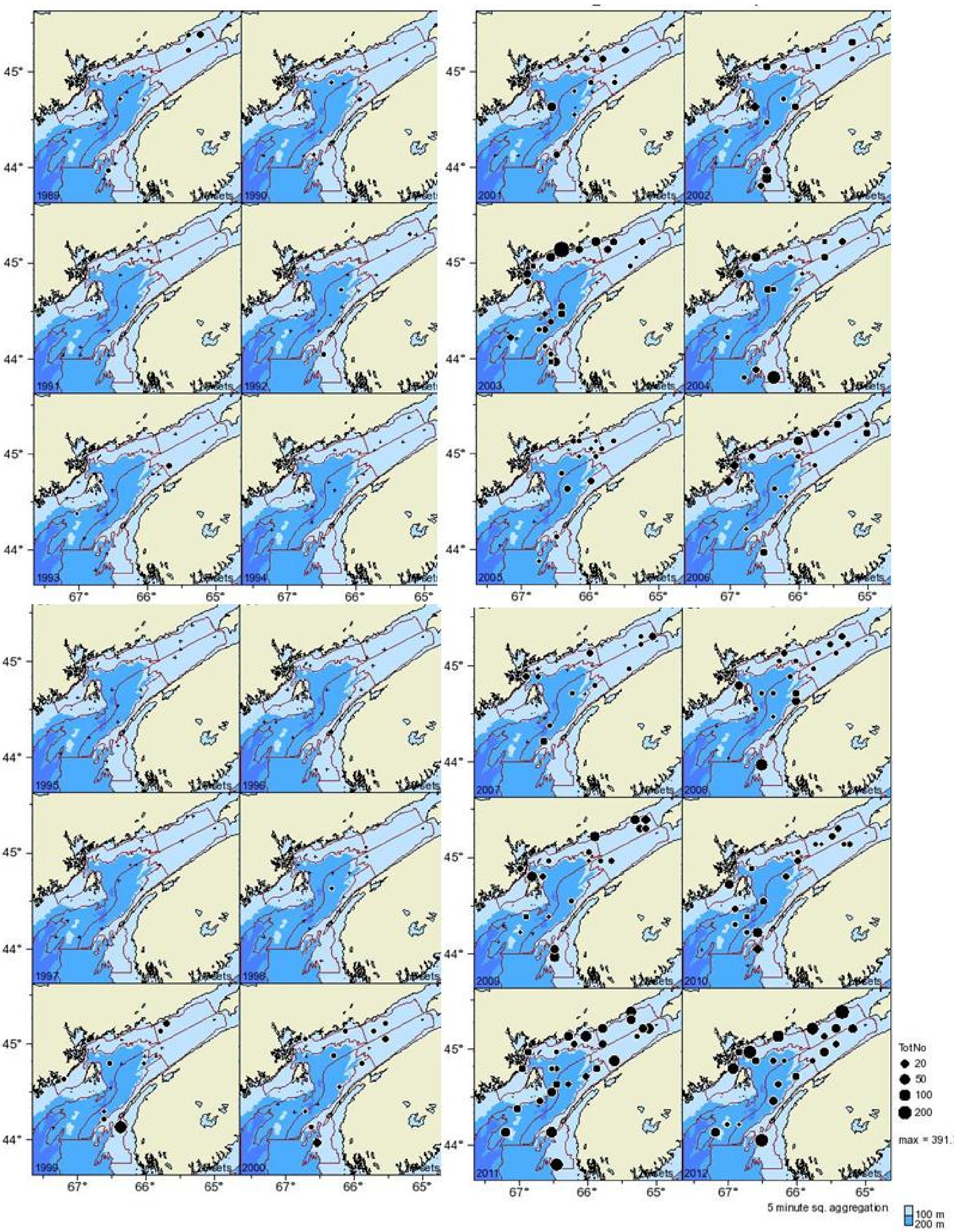

Figure 8. Lobster catch in Summer RV survey (Bay of Fundy, Strata 490-495), 1989-2012. Shown is mean adjusted number per tow.

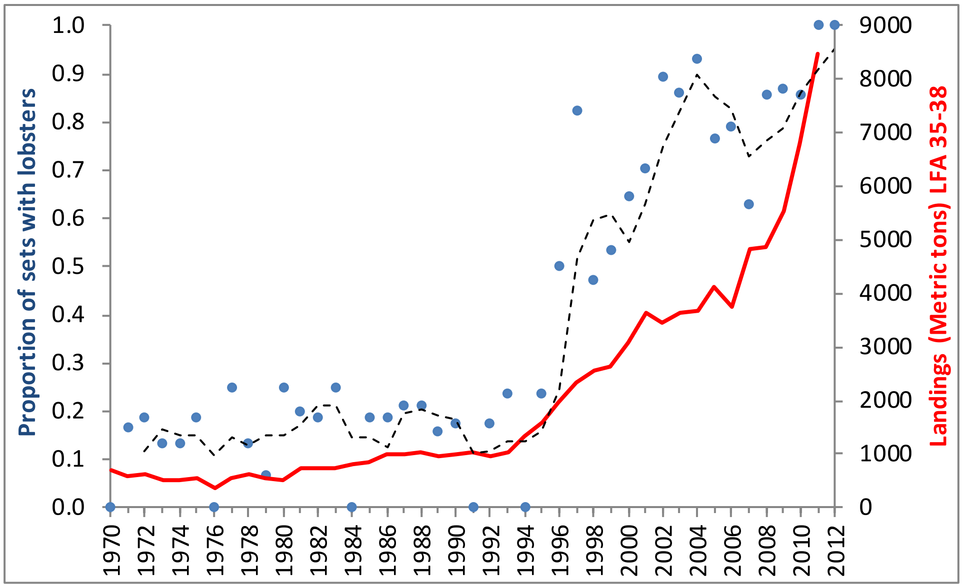

Figure 9. Proportion of sets in the Summer RV survey (Bay of Fundy, Strata 490-495) with lobsters (solid blue circles), and the 3 year moving average (dashed line). Also shown are LFA 35-38 lobster landings (red line). Landings are for season following RV survey; e.g., latest landings shown are for 2011-2012 and are aligned with 2011 survey year.

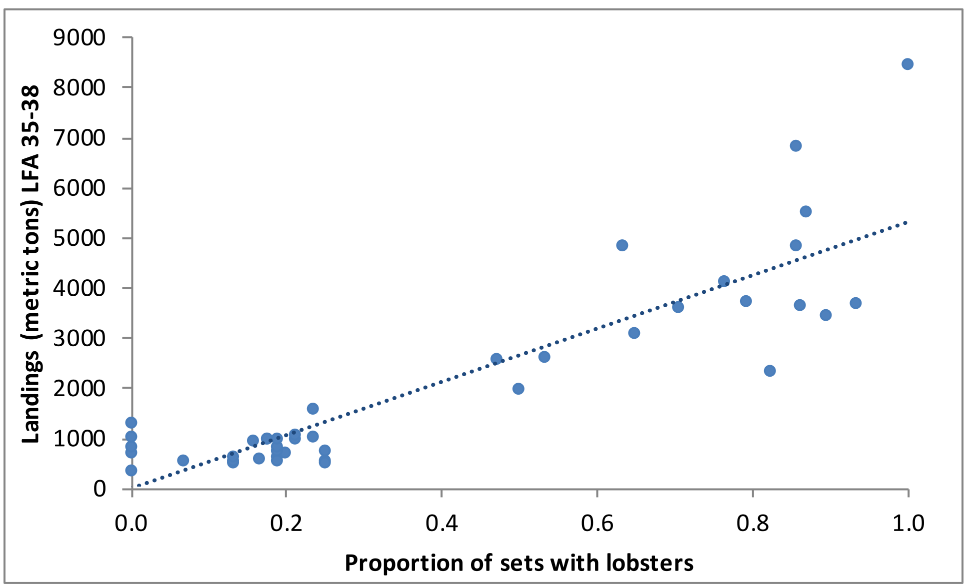

Figure 10. Proportion of sets with lobsters in the Summer RV survey (Bay of Fundy, Strata 490-495, 1970-2012) vs. landings in LFA 35-38. Landings are for year following survey. Dotted line is linear fit.

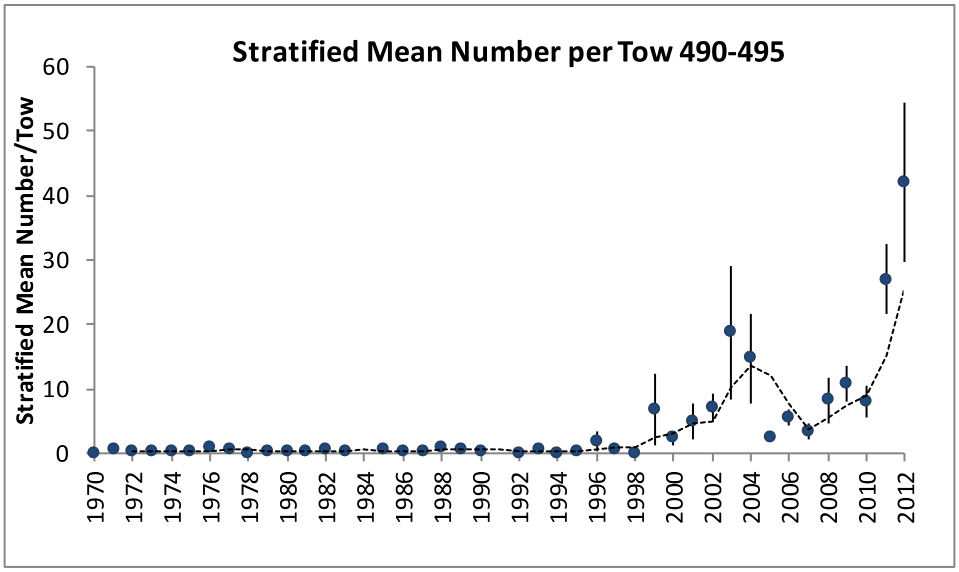

Figure 11. Stratified mean number per tow with Standard Error SE) in the Summer RV survey (Bay of Fundy, Strata 490-495) and the 3-year moving average (dashed line). Templeman or Teleost survey vessels were used in 2004, 2007 and 2008.

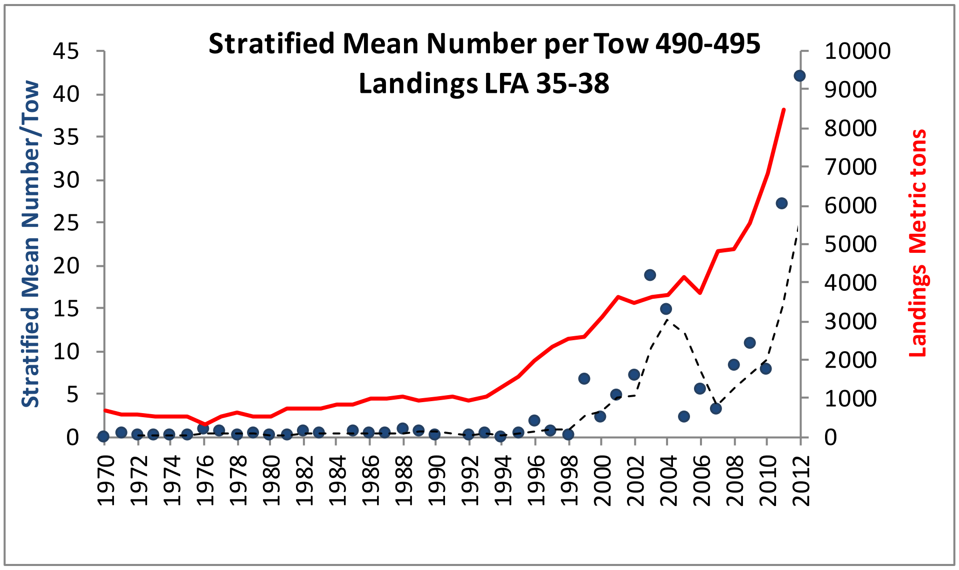

Figure 12. Stratified mean number per tow (solid circles) in the Summer RV survey (Bay of Fundy, Strata 490-495) and the 3-year moving average (dashed line). Also shown are LFA 35-38 lobster landings (red line). Landings are for season following RV survey; e.g., latest landings shown are for 2011-2012 and are aligned with 2011 survey year.

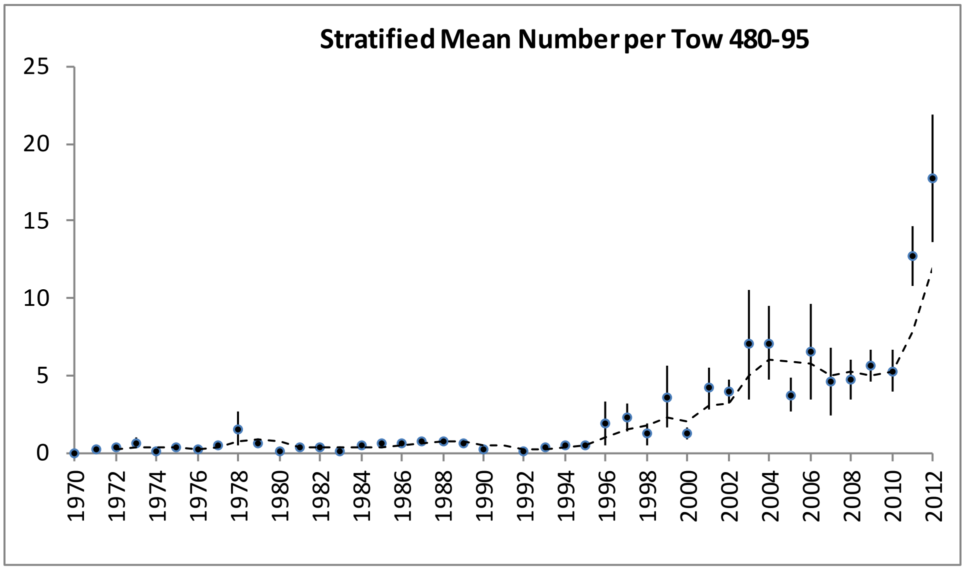

Figure 13. Stratified mean number per tow with Standard Error (SE) in the Summer RV survey (E. Gulf of Maine, Strata 480-495) and the 3-year moving average (dashed line). Templeman or Teleost survey vessels were used in 2004, 2007 and 2008.

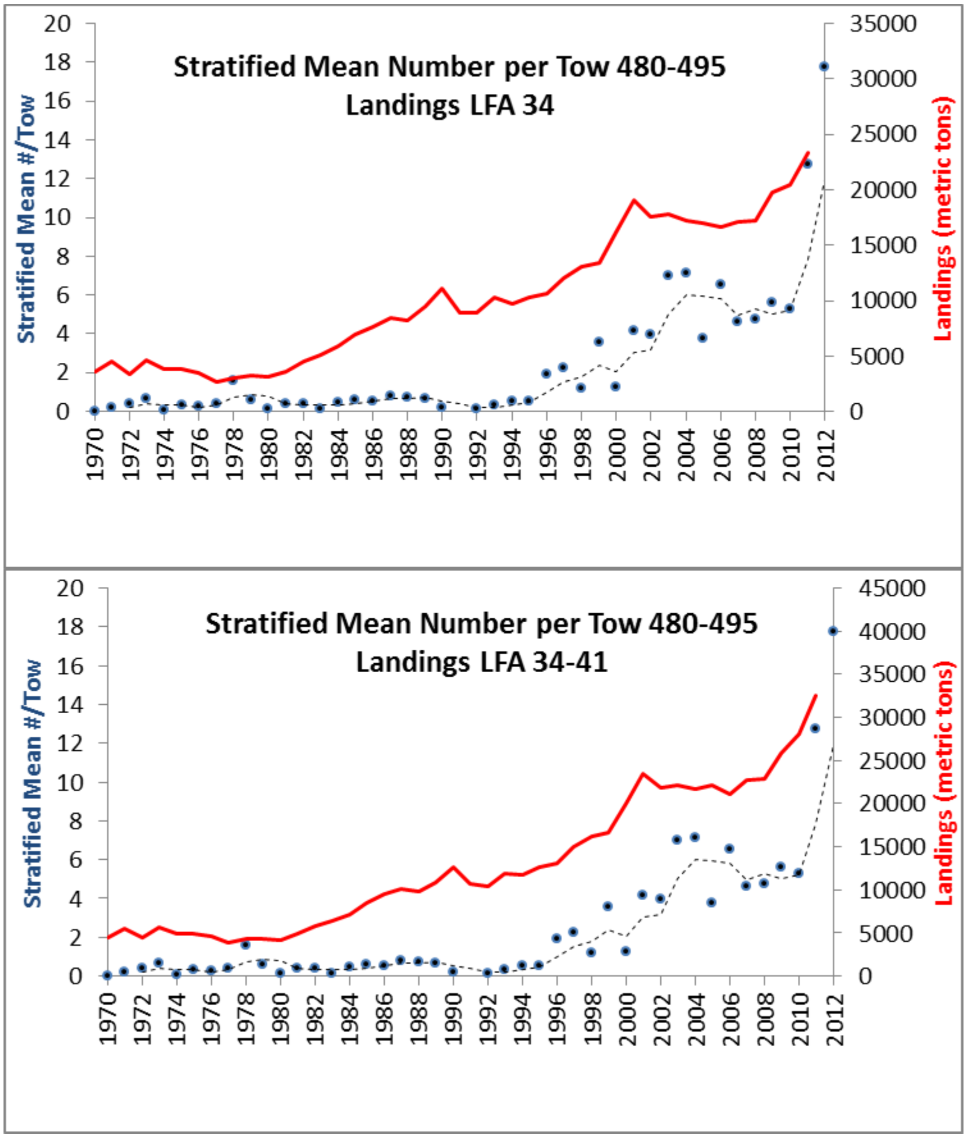

Figure 14. Stratified mean number per tow (solid circles) in the Summer RV survey (E. Gulf of Maine, Strata 490-495) and the 3-year moving average (dashed line). Also shown are landings for LFA 34 and for LFAs 34-41. Landings are for the season following the RV survey; e.g., latest landings shown are for 2011-2012 and are aligned with 2011 survey year.

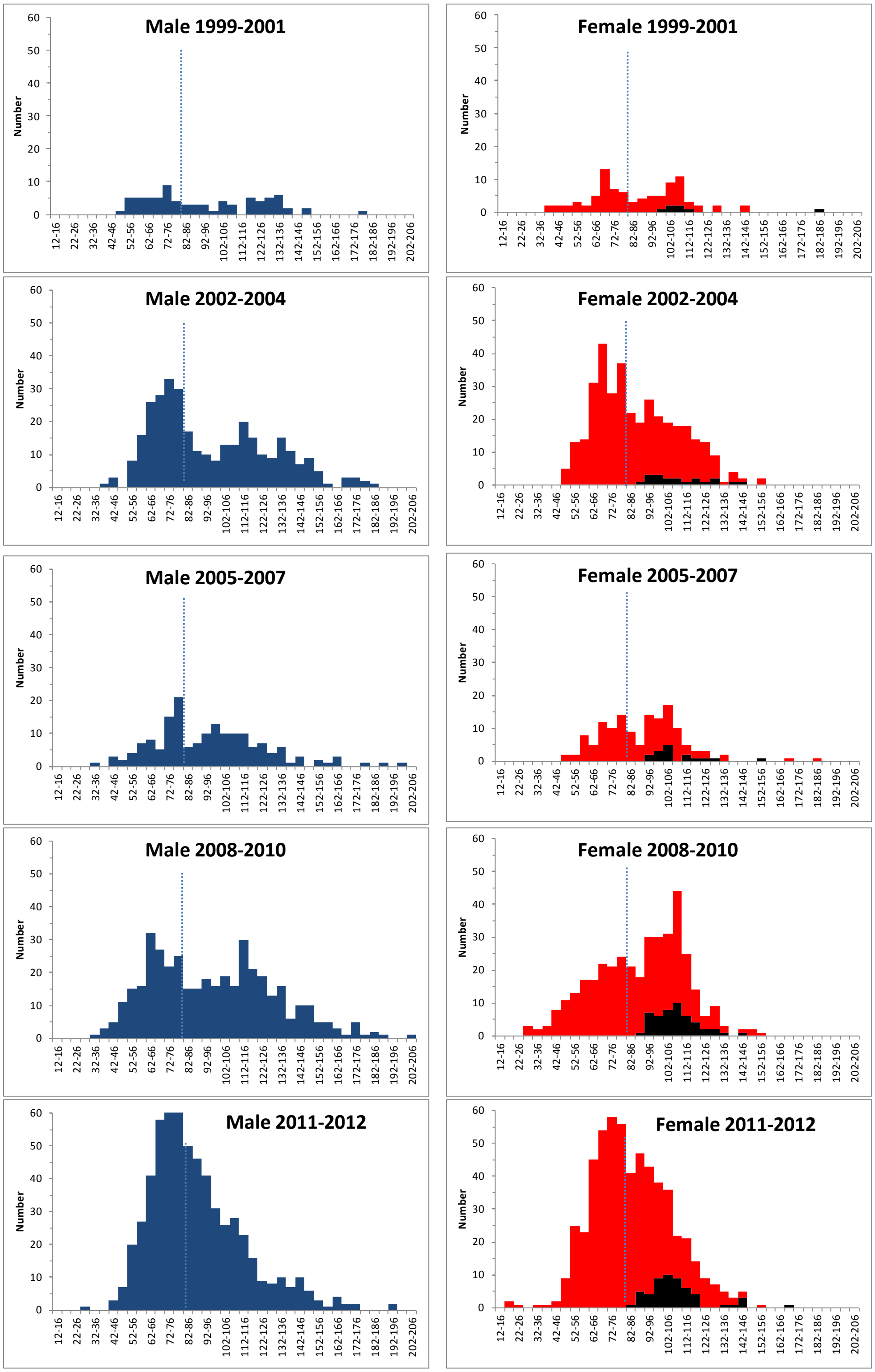

Figure 15. Lobster size frequencies in Bay of Fundy from Maritimes Summer RV survey (Strata 490-495). Colours represent sex or reproductive state: males (blue), females without eggs are (red), and ovigerous females (black).

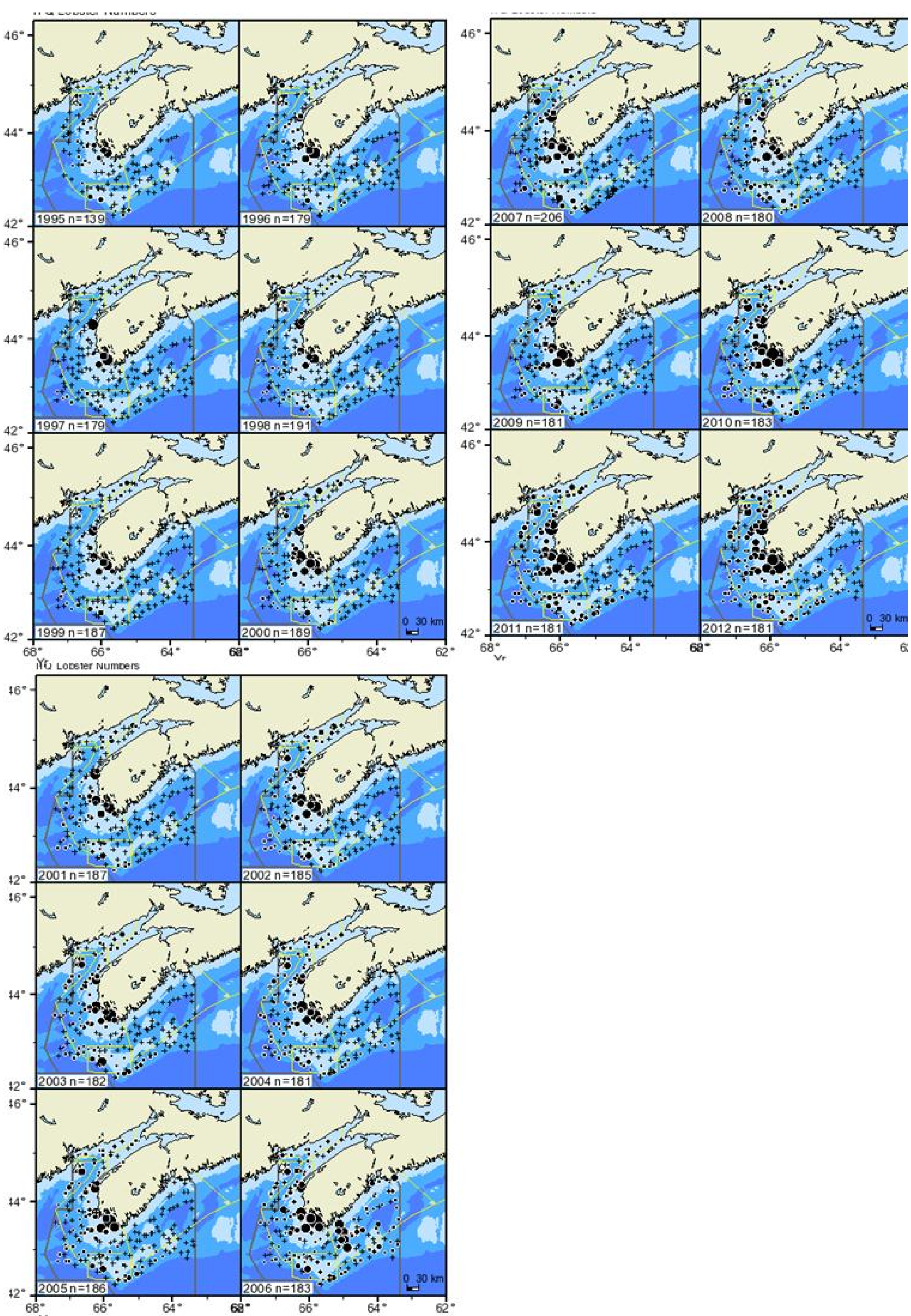

Figure 16. ITQ survey number per tow, 1995-2012.

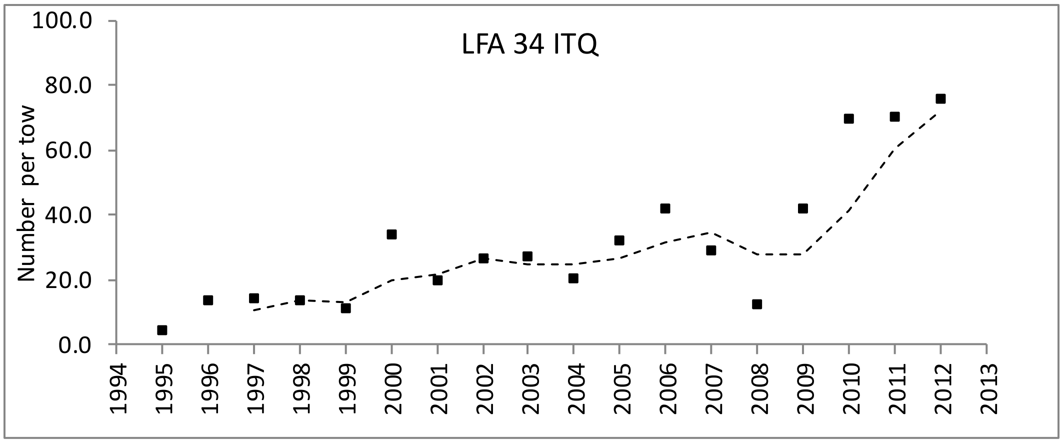

Figure 17. Mean number per tow from the ITQ survey for LFA 34. Dashed line is 3-yr moving average.

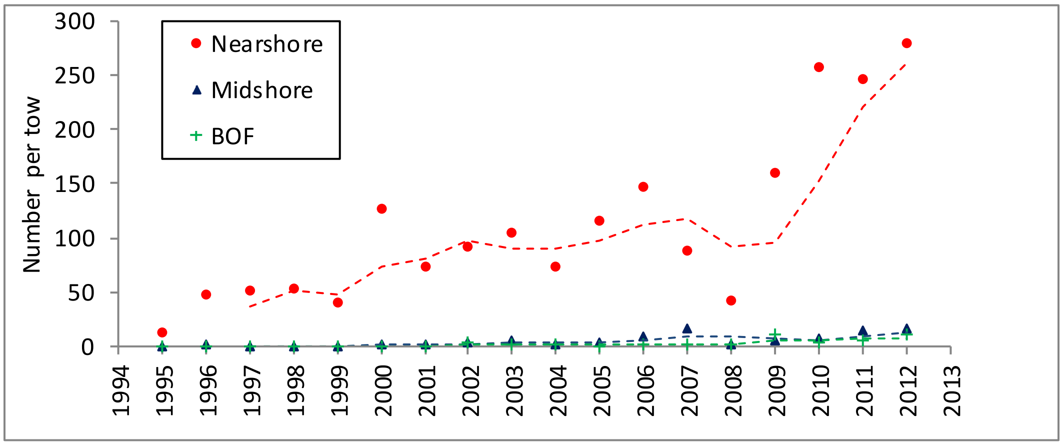

Figure 18. Mean number per tow from the ITQ survey for LFA 34: Nearshore, Midshore and Bay of Fundy (BOF) portion of LFA 34 (GG 7) (see Figure 6 for map). Dashed lines are 3-yr moving averages.

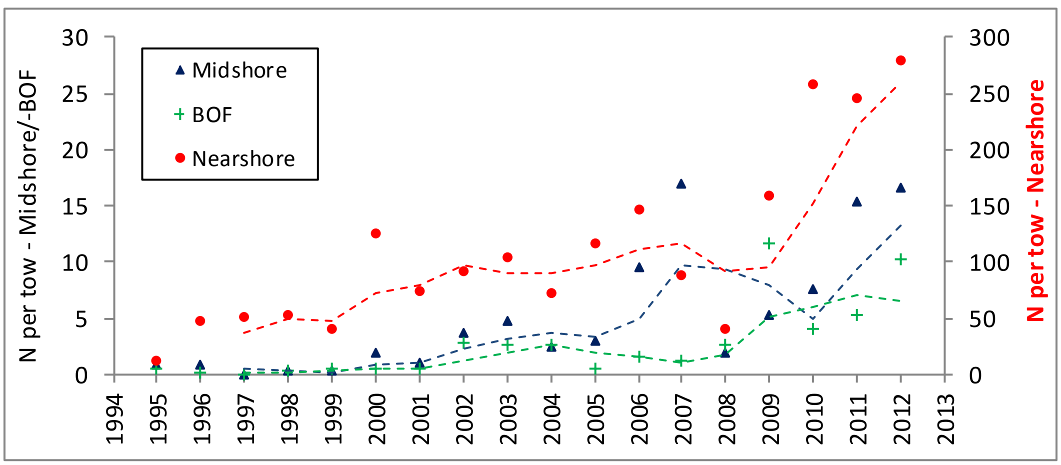

Figure 19. Mean number per tow from the ITQ survey for LFA 34: Nearshore, Midshore and Bay of Fundy (BOF) portion of LFA 34 (GG 7) (see Figure 6 for map). Dashed lines are 3-yr moving averages. Note different scale for Nearshore.

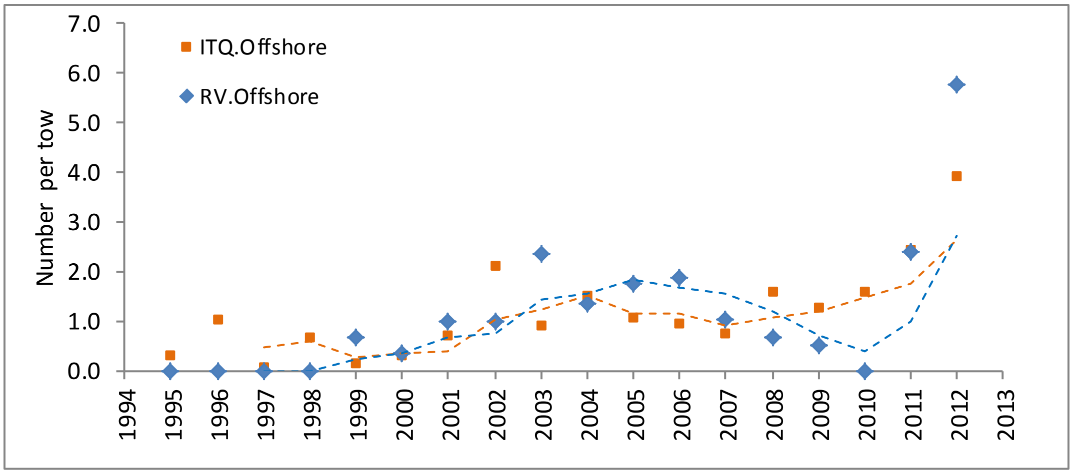

Figure 20. Mean number per tow in offshore of LFA 34 from the ITQ survey and the RV survey (stratum 484). Dashed lines are 3-yrear moving averages.

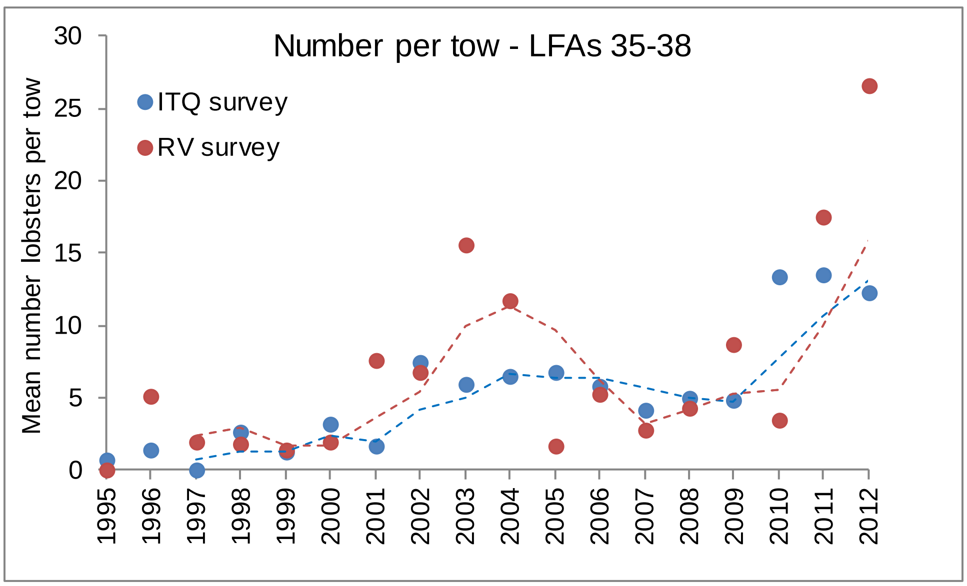

Figure 21. Mean number per tow in the Bay of Fundy portion of the ITQ (LFAs 35-38 only) and the RV survey (strata 492-495). Dashed lines are 3-yrear moving averages.

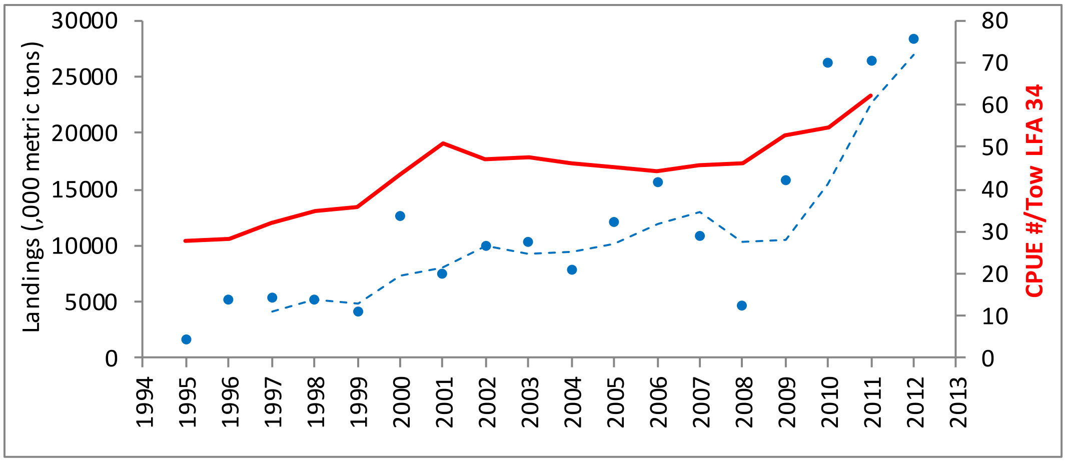

Figure 22. Mean number per tow from the ITQ survey for all of LFA 34 (solid circles) and commercial landings (red line). Dashed line is 3-yr moving average of ITQ survey mean. Landings are for season following ITQ survey e.g. latest landings shown are for 2011-12 and are aligned with 2011 survey year.

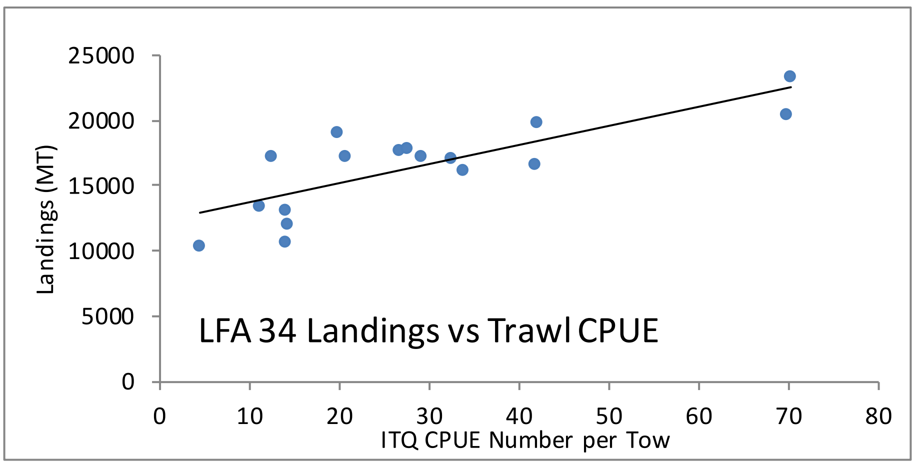

Figure 23. Commercial landings for LFA 34 versus mean number per tow from ITQ survey. Line is a linear fit. Landings are for season following ITQ survey.

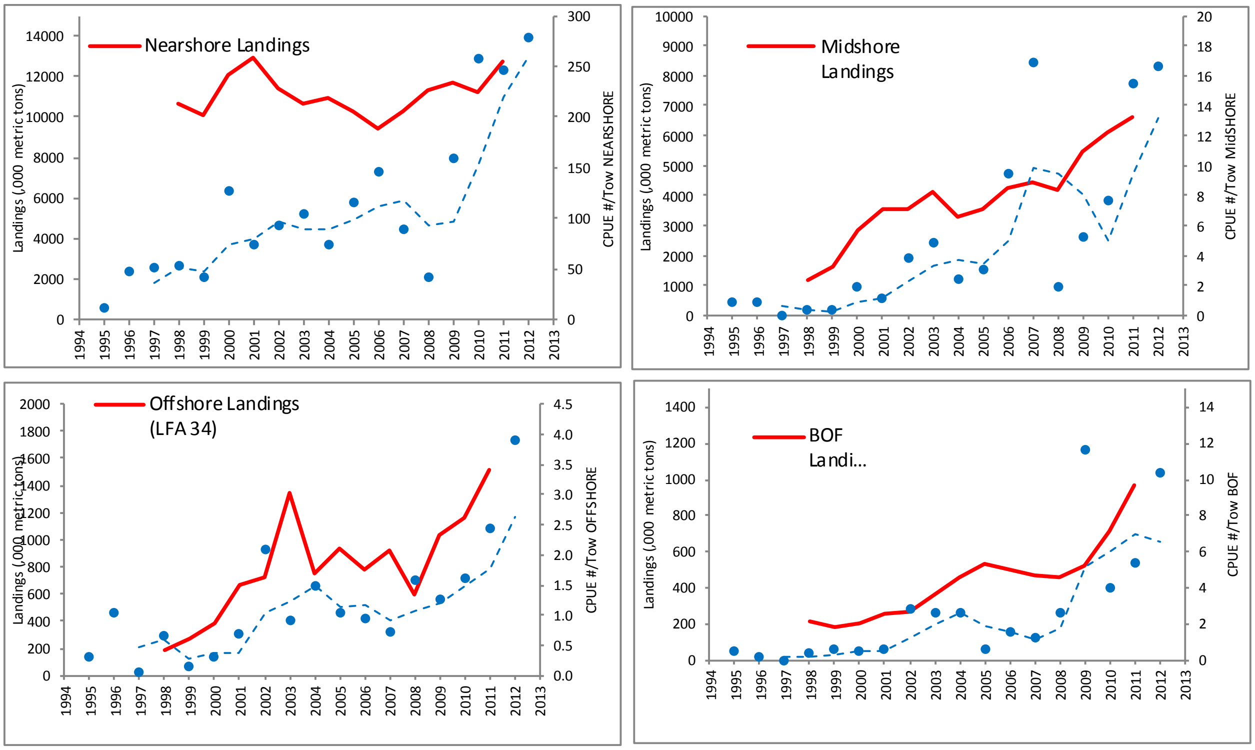

Figure 24. Mean number per tow (closed circles) from the ITQ survey and commercial landings (solid line) for different parts of LFA 34. Shown is nearshore (upper left), midshore (upper right), offshore (lower left) and Bay of Fundy (BOF) portion of LFA 34 (lower right). Dashed line is 3-yr moving average of ITQ survey mean for relevant areas. Landings are for season following ITQ survey. Note that landings by grid are needed to estimate origin of LFA 34 landings, and grids were not in place until 1998.

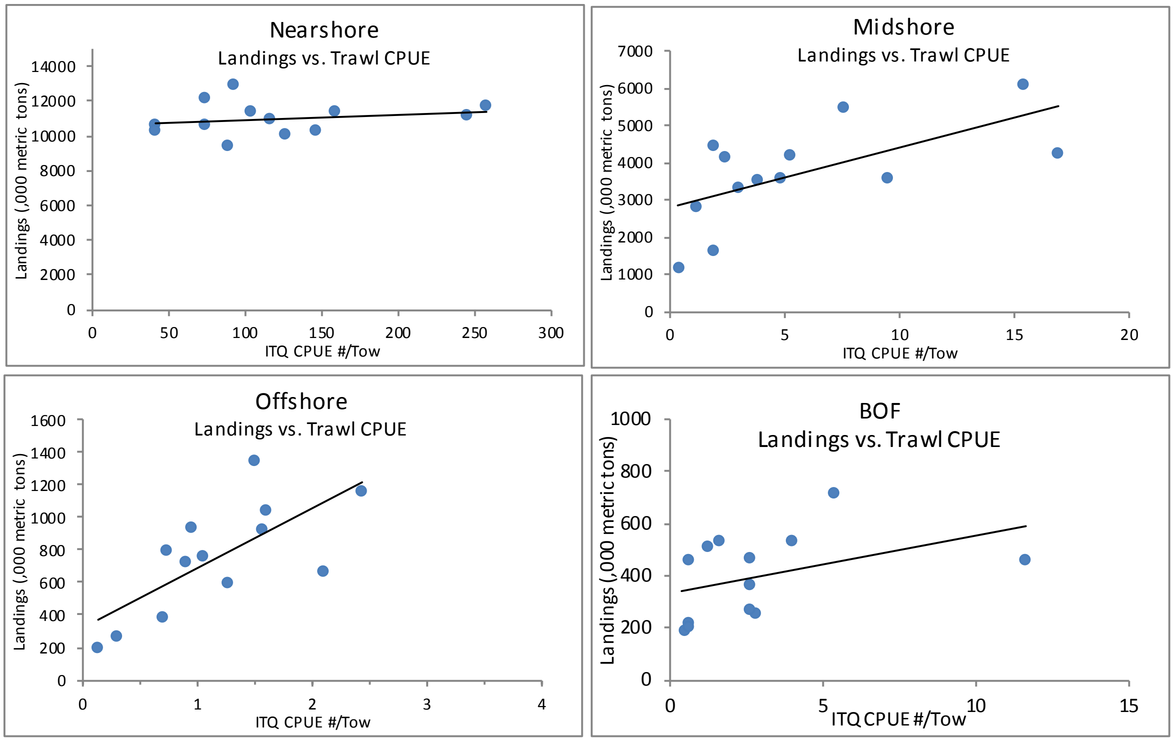

Figure 25. Landings vs. ITQ survey mean number per tow for Nearshore, Midshore, Offshore and Bay of Fundy (BOF) portions of LFA 34. Landings are for season following ITQ survey. Line is a linear fit.

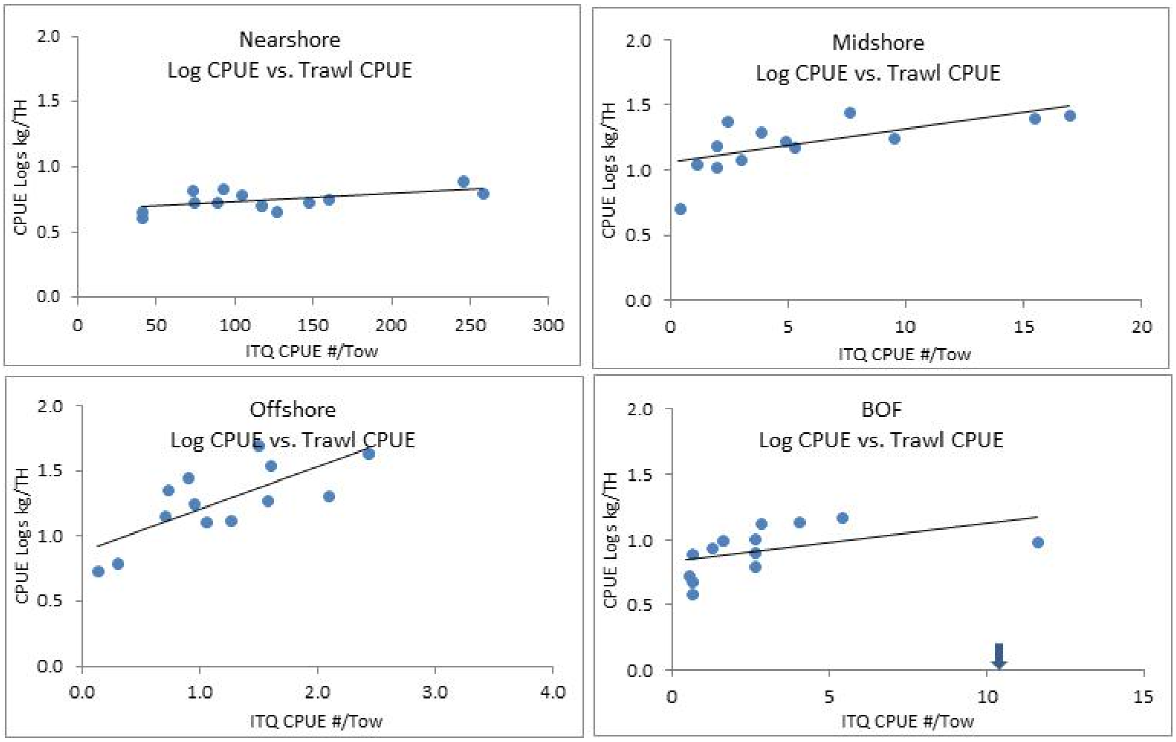

Figure 26. Logbook CPUE vs. ITQ survey mean number per tow for Nearshore, Midshore, Offshore and Bay of Fundy (BOF) portions of LFA 34. Logbook CPUE is for season following ITQ survey. Line is a linear fit.

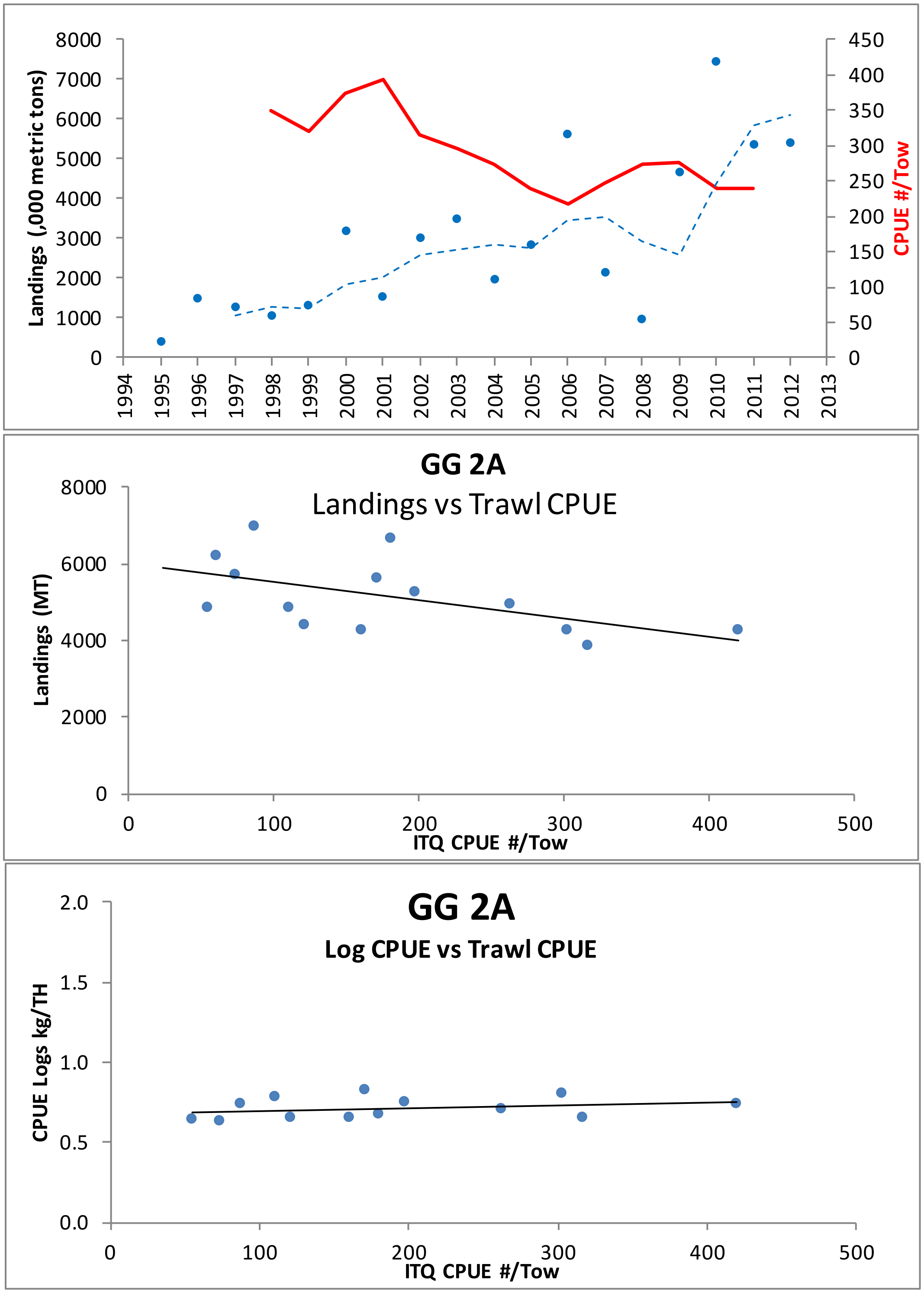

Figure 27. Detail for GG 2A (Lobster Bay). Upper panel: Mean number per tow from ITQ survey, 3-year moving average (dotted line) and landings; middle panel: Landings in GG 2A vs. ITQ mean number per tow with linear fit; bottom panel: Logbook CPUE vs. ITQ mean number per tow.

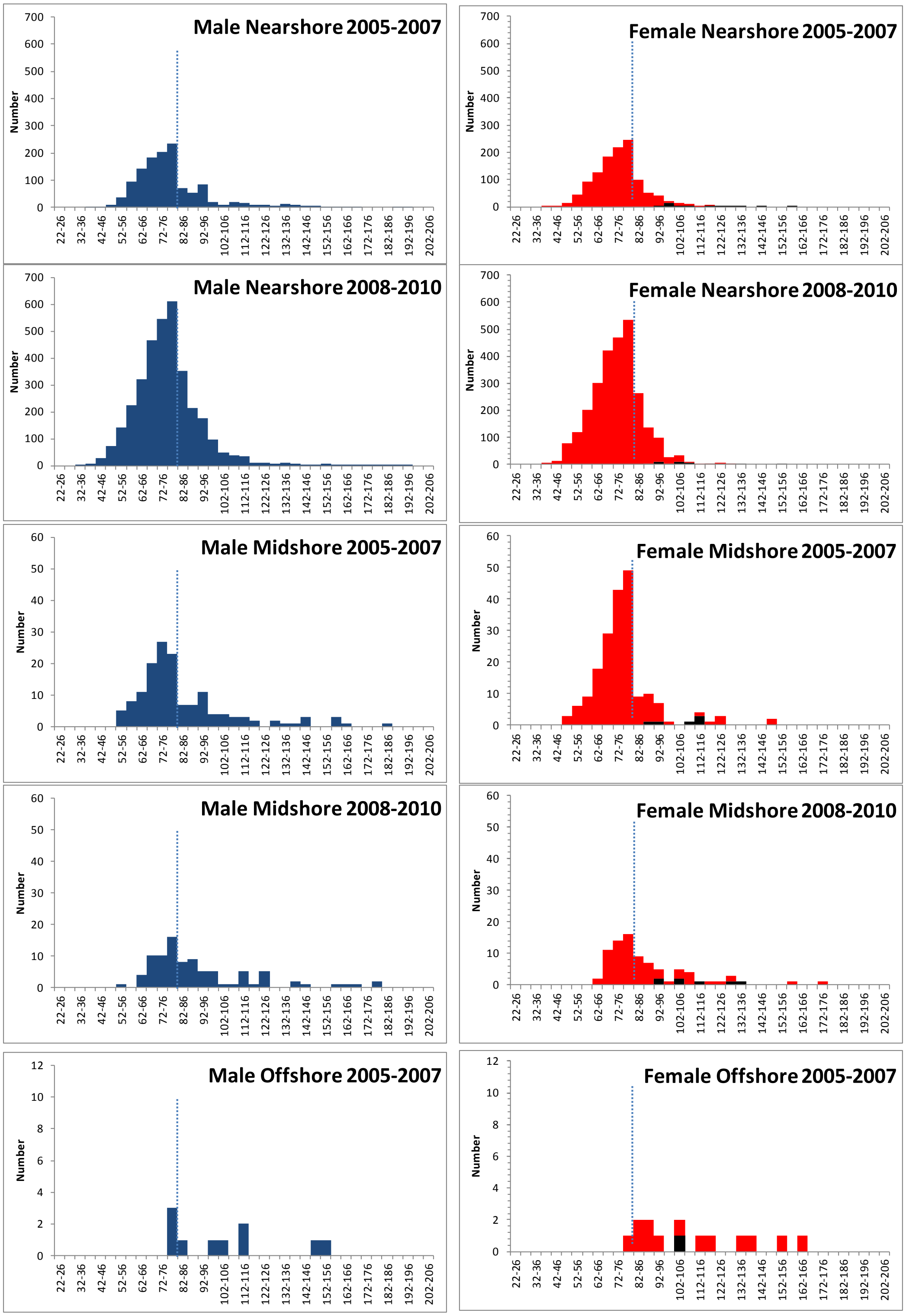

Figure 28. Example lobster size frequencies from ITQ survey (July). Nearshore, midshore and offshore areas are depicted in Figure 6. Blue = males, red = non-egged females, black = egged females. Vertical dotted line indicates minimum legal size in commercial fishery. Note different scale ranges for vertical axes.

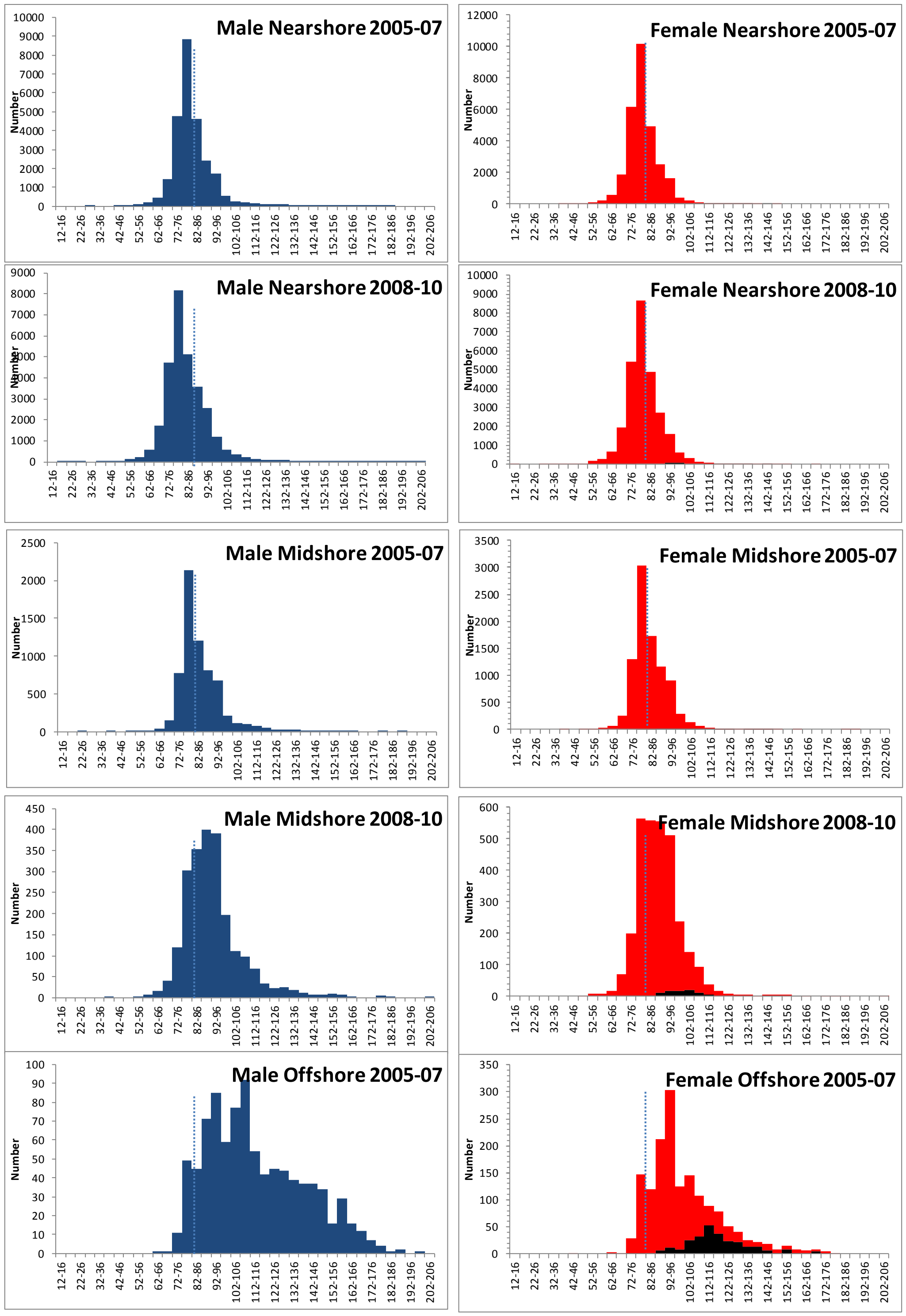

Figure 29. Example lobster size frequencies from at-sea samples of the fishery in LFA 34. Nearshore, midshore and offshore areas depicted in Figure 6. Blue = males, red = non-egged females, black = egged females. Vertical dotted line = minimum legal size in commercial fishery. Note different scale ranges for vertical axes.

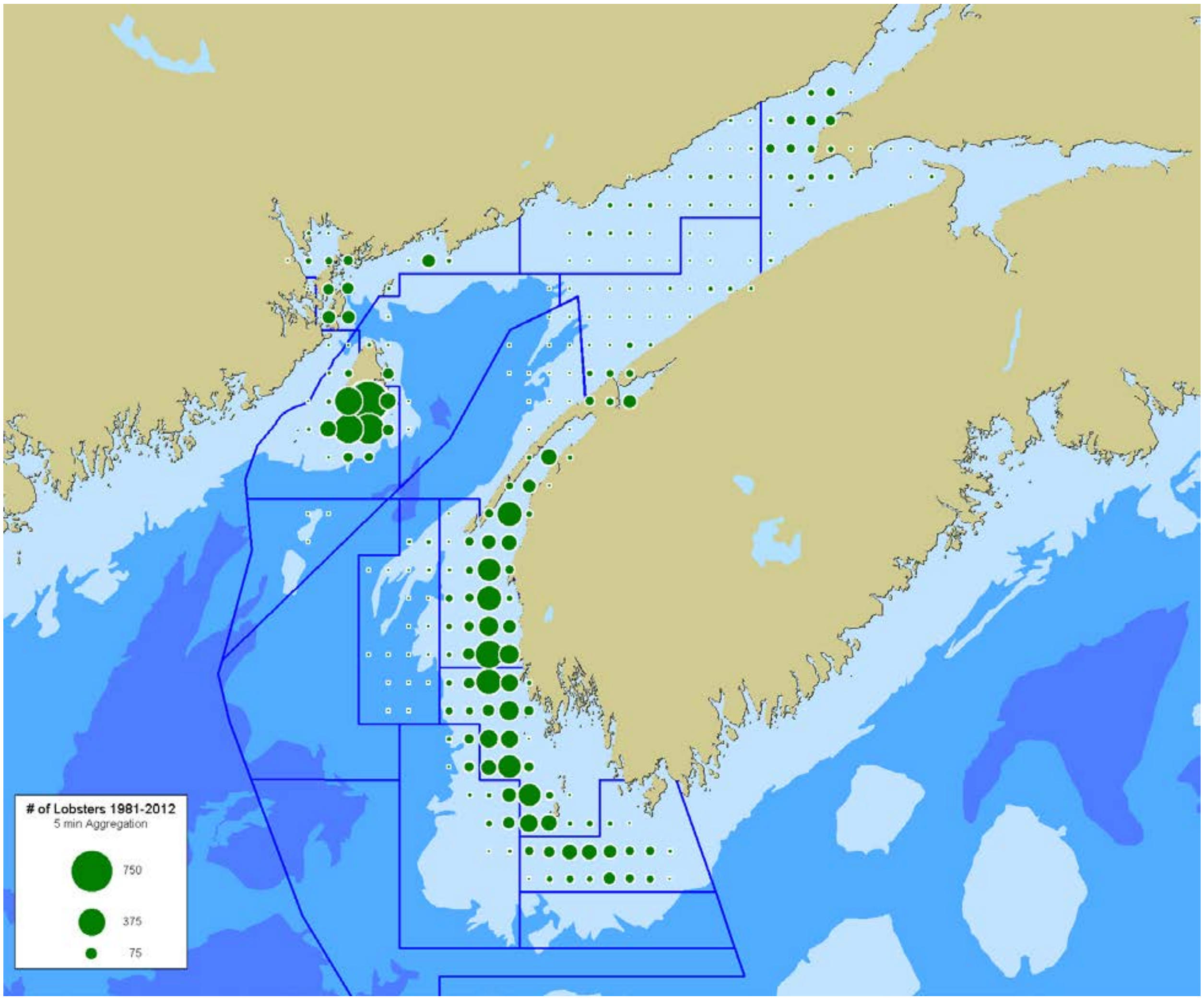

Figure 30. Total number of lobsters caught in scallop surveys 1981-2012. Data were aggregated by 5-minute grids.

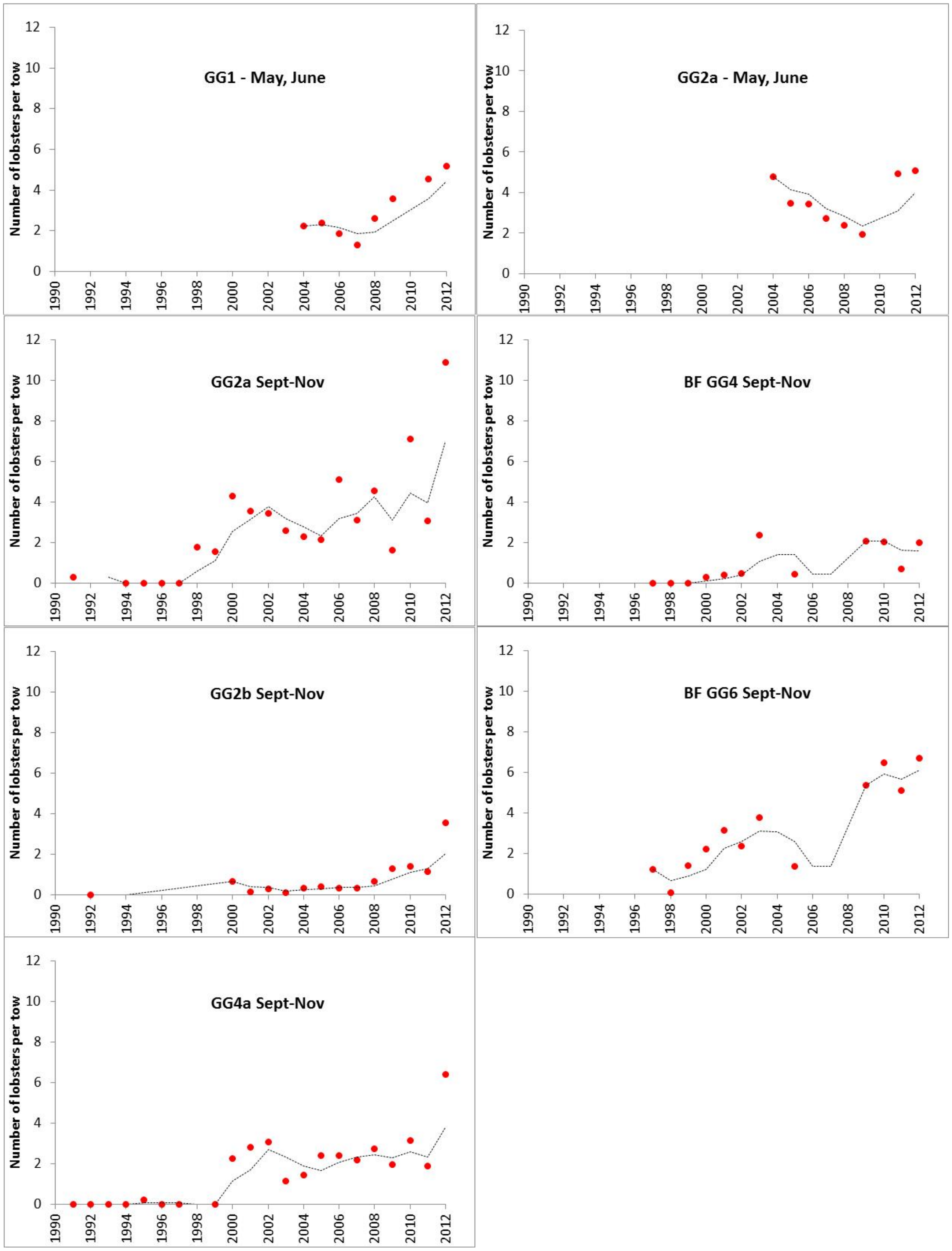

Figure 31. Mean number per tow from scallop surveys (solid circles) for Grid Groups (see Figure 5) with (i) data in the last 9 years (2004-2012) and (ii) mean number of lobsters per tow for the last 9 years of at least 1. Upper two panels show Grid Groups with scallop surveys in May or June; lower five panels show Grid Groups with scallop surveys in September, October or November. Data from July-August excluded.

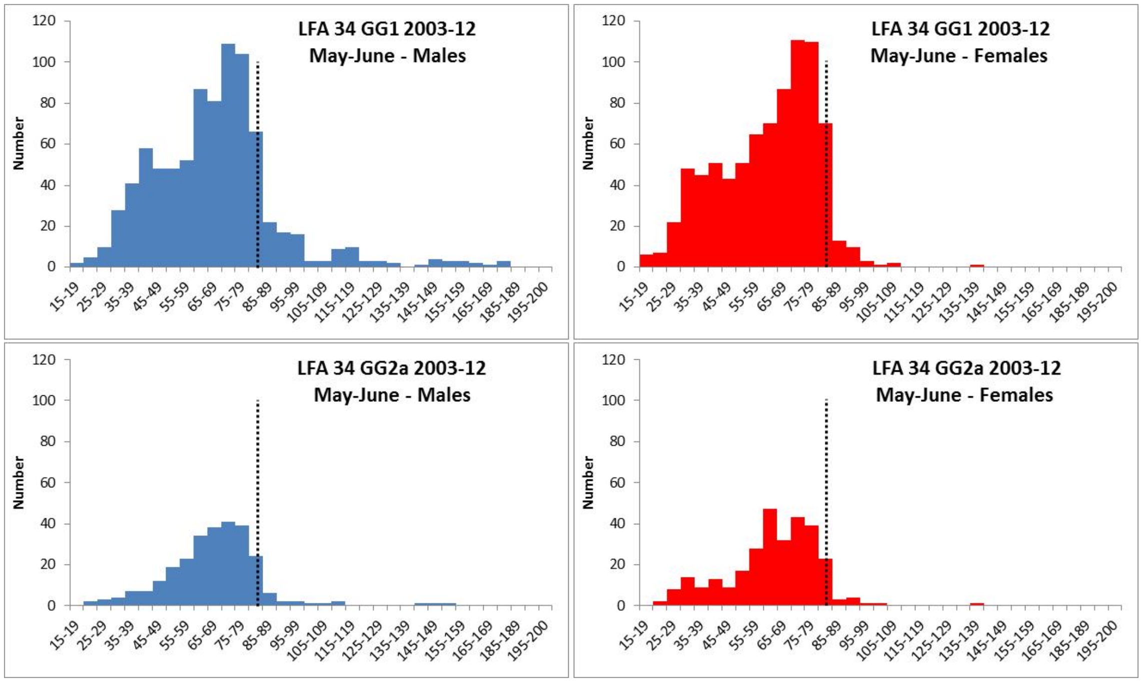

Figure 32. Size frequency of lobsters sampled in May-June scallop surveys for selected Grid Groups (upper two panels in Figure 31). Total lobsters measured for period and Grid Group are shown. Females shown were non-egged; egged females were very rare. Minimum legal size (82.5 mm CL) is within size bin indicated by vertical dotted line.

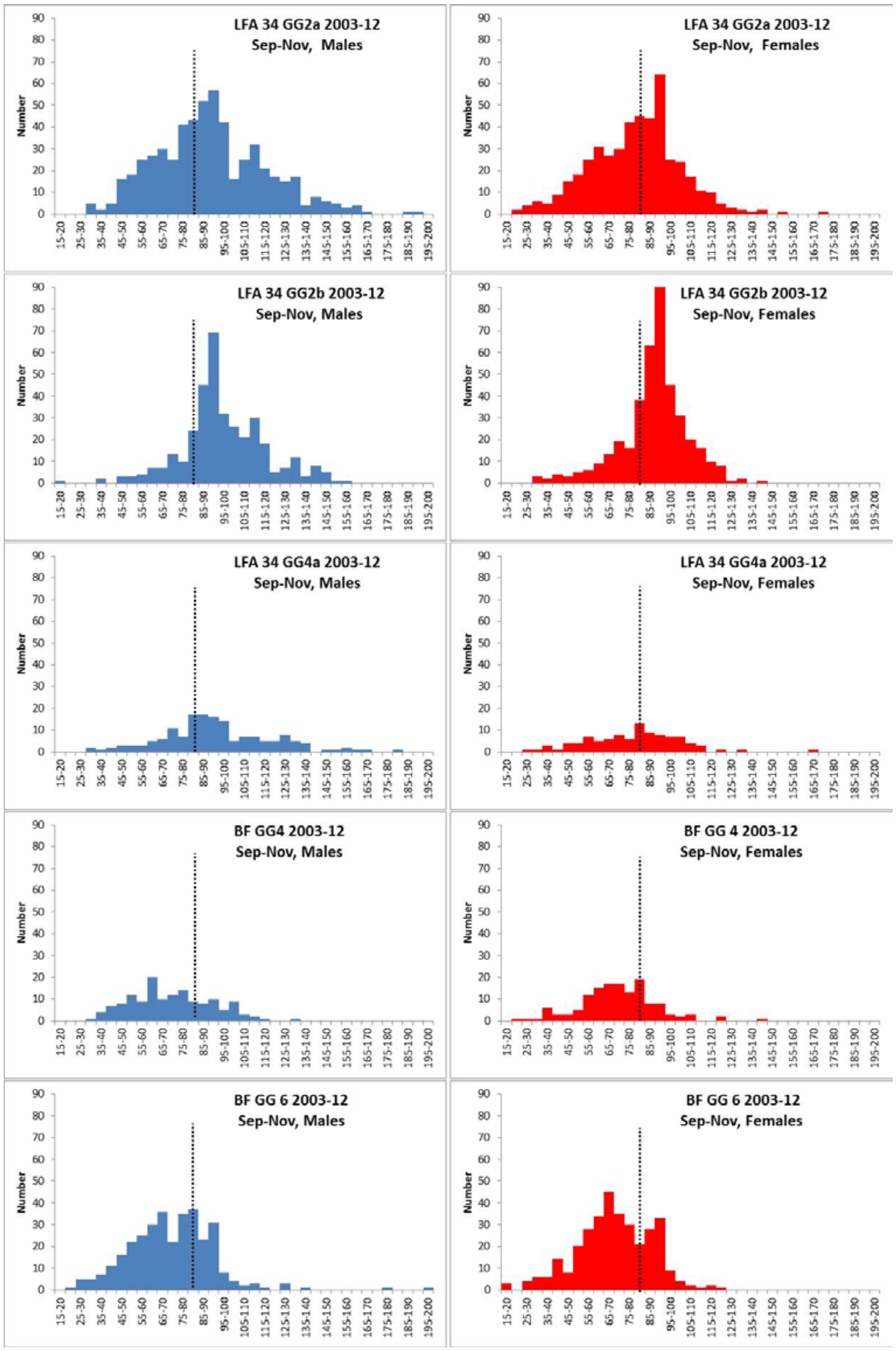

Figure 33. Size frequency of lobsters samples in in September to November for selected Grid Groups (lower 5 panels in Figure 31). Total lobsters measured for period/Grid Group are shown. Females shown were non-egged; egged females were very rare. Minimum legal size (82.5 mm CL) is within size bin indicated by vertical dotted line.